
CLAIMS

[Claim(s)]
[Claim 1] In the plasma treatment equipment which has a vacuum processing room, the plasma production means containing the electrode of a pair, the sample base that has the sample installation side in which the sample processed in this vacuum processing interior of a room is laid, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the high-frequency power of VHF ** (30MHz thru/or 300MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator Plasma treatment equipment characterized by having the magnetic field means forming which forms a static magnetic field or a low frequency magnetic field, and forming the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[Claim 2] In the plasma treatment equipment which has a vacuum processing room, the plasma production means containing the electrode of a pair, the sample base in which the sample processed in this vacuum processing interior of a room is laid while serving as one side of said electrode, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the VHF electrification force (50MHz thru/or 200MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator It has the magnetic field means forming which forms the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency magnetic field. Said magnetic field means forming is set up so that the part used as the max of the component of a direction along the field of said sample base of said magnetic field may become said sample base and opposite side from the center of the electrode of said pair. Plasma treatment equipment characterized by forming the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[Claim 3] Plasma treatment equipment characterized by making the reinforcement of the magnetic field formed of said magnetic field means forming a magnetic field component parallel to this side become 30 gauss or less on said sample side in claims 1 or 2.
[Claim 4] In the plasma treatment equipment which has a vacuum processing room, a plasma production means containing the electrode of a pair, and a sample base for arranging the sample processed in this vacuum processing interior of a room while serving as one side of said electrode The RF generator which impresses VHF ****** (30MHz thru/or 300MHz) to inter-electrode [of said pair], Said electrode is constituted by the 1st electrode connected to said RF generator, and the 2nd electrode connected to the bias power supply for ion energy control while serving both as said sample base. A reduced pressure means for the inter-electrode distance of this pair to be 30 thru/or 100mm, and to decompress said vacuum processing room to 0.4Pa thru/or 4Pa, It has the magnetic field means forming which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field in the direction which intersects the electric field of inter-electrode [of said pair], or the neighborhood of it. Plasma treatment equipment characterized by forming the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator in said 1st electrode side rather than said 1st electrode surface top or the center of two electrodes.
[Claim 5] Plasma treatment equipment characterized by constituting so that the consistency or direction of said field formed of said magnetic field means forming may be adjusted and a plasma consistency may become homogeneity in the location corresponding to the whole surface of said sample installation side in either of claims 1 , 2 , or 4 so that the cyclotron resonance effectiveness of said electron may become large on the periphery of this sample , or its outside compared with the center of said sample .
[Claim 6] Plasma treatment equipment with which said magnetic field means forming is characterized by including the core which changes said magnetic field by carrying out eccentricity and rotating to the core

of said sample side, and changes continuously the distance of said cyclotron-resonance field to said sample in claim 4.
[Claim 7] In the plasma treatment equipment which has a vacuum processing room, the plasma production means containing the electrode of a pair, the sample base that has the sample installation side in which the sample processed in this vacuum processing interior of a room is laid, and a reduced pressure means to decompress said vacuum processing room The 1st electrode by which said electrode was connected to the RF generator, and the 2nd electrode which serves both as said sample base, It is constituted by the amount of [of said processing room which was located in the circumference outside of said 1st electrode, and was grounded] wall. Said RF generator between inter-electrode [of said pair], and the wall part of said 1st electrode and said processing room It is the power source which impresses the high-frequency power of VHF ** (30MHz thru/or 300MHz). In the direction mutually superimposed by denial **** and circumference ****** of said processing room near the core of said processing room It has the magnetic field means forming which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field. Plasma treatment equipment characterized by forming the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator a periphery or near [its] an outside said sample installation side.
[Claim 8] Plasma treatment equipment with which said magnetic field means forming is characterized by having two or more coils arranged around said processing room so that magnetic flux may be mutually negated near the center of said sample and magnetic flux may be made to superimpose mutually on the periphery of this sample, or its outside in claim 7.
[Claim 9] Plasma treatment equipment characterized by duty of the forward direction pulse part adding 0.4 or less pulse bias to said sample through a capacitative element in a period as bias power supply for said ion energy control in 0.2 - 5 microseconds in claim 4.
[Claim 10] The plasma-treatment equipment characterized by to establish an electrostatic adsorption means hold said sample on said sample base by electrostatic adsorption power, a pulse bias impression means connect with said sample base and impress pulse bias voltage to this sample base, and an electrical-potential-difference control means control the rise of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means, in either of claims 1, 2, or 4.
[Claim 11] It is plasma treatment equipment characterized by being constituted so that said electrical-potential-difference control means may control the electrical-potential-difference change by the electrostatic adsorption film of said electrostatic adsorption means in a round term of a pulse or less [of said pulse bias voltage] to 1/2 in claim 10.
[Claim 12] A vacuum processing room, the plasma production means containing the electrode of a pair, and the sample base for arranging the sample processed in this vacuum processing interior of a room while serving as one side of said electrode, In the plasma treatment approach of the sample by the plasma treatment equipment which has a reduced pressure means to decompress said vacuum processing room By the step which decompresses said vacuum processing interior of a room with a reduced pressure means, and magnetic field means forming The step which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field in the direction which intersects the inter-electrode electric field of said pair, VHF ****** (30MHz thru/or 300MHz) is impressed to inter-electrode [of said pair] by the RF generator. Between the electrodes of said pair The plasma treatment approach characterized by having the step which processes said sample by the plasma by which ** Li generation is carried out at the step which forms the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator, and the cyclotron resonance of said electron.
[Claim 13] In the plasma treatment approach of the sample by the plasma treatment equipment which has a vacuum processing room, a sample base for arranging the sample processed in this vacuum processing interior of a room, and a plasma production means containing the electrode of a pair It is constituted by the electrode of a pair with which said electrode consists of the 1st electrode connected to said RF generator, and the 2nd electrode connected to the bias power supply for ion energy control while serving both as said sample base. By the step which the inter-electrode distance of this pair is 30 thru/or 100mm, and decompresses said vacuum processing interior of a room to 0.4Pa thru/or 4Pa with a reduced pressure means, and magnetic field means forming The step which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field in the direction which intersects the inter-electrode electric field of said pair, The VHF electrification force (30MHz thru/or 300MHz) is impressed to inter-electrode [of said pair] by the RF generator. Between the electrodes of said pair The

plasma treatment approach characterized by having the step which processes said sample by the plasma by which ** Li generation is carried out at the step which forms the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator, and the cyclotron resonance of said electron.
[Claim 14] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, While having a pulse bias impression means to impress pulse bias voltage to said sample and impressing the high-frequency voltage of 10MHz - 500MHz as said RF generator Plasma treatment equipment characterized by being constituted so that said vacuum processing room may be decompressed to 0.5-4.0Pa.
[Claim 15] The electrode with which the pair by which a sample is arranged counters one electrode, and a gas installation means to introduce etching gas into the ambient atmosphere by which said sample is arranged, An exhaust air means to evacuate said ambient atmosphere to 0.5-4.0Pa, and the RF generator which impresses the high-frequency voltage of 10MHz - 500MHz to the counterelectrode of said pair, Plasma treatment equipment characterized by consisting of a plasma production means to plasma-ize said etching gas under said pressure, and a pulse bias impression means to impress pulse bias voltage at one [said] electrode at the time of etching of said sample, and carrying out plasma treatment of the insulator layer in said sample.
[Claim 16] A vacuum processing room and the sample base for arranging the sample processed at this vacuum processing room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A pulse bias impression means to connect with said sample base and to impress pulse bias voltage to this sample base, An electrical-potential-difference control means to control the rise of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means is established. This electrical-potential-difference control means Plasma treatment equipment characterized by being constituted so that the electrical-potential-difference change by the electrostatic adsorption film of said electrostatic adsorption means in a round term of a pulse may be controlled or less [of said pulse bias voltage] to 1/2.
[Claim 17] An electrostatic adsorption means to hold a sample by electrostatic adsorption power to the electrode with which the pair whose gap is 10mm - 50mm counters, and said one electrode, A gas installation means to introduce etching gas into the ambient atmosphere in which said sample was held, An exhaust air means to evacuate said ambient atmosphere to 0.5-4.0Pa, and a plasma production means to plasma-ize said etching gas with 10MHz - 500MHz high-frequency power under said pressure, Plasma treatment equipment characterized by consisting of a pulse bias impression means to impress pulse bias voltage to one [said] electrode with which said sample has been arranged, and carrying out plasma treatment of the insulator layer in said sample.
[Claim 18] In plasma treatment equipment given in either of claims 16 or 17 An electrical-potential-difference control means to control the rise of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means is established. As said electrical-potential-difference control means Plasma treatment equipment characterized by setting up the period of said pulse bias voltage so that the electrical-potential-difference change by the electrostatic adsorption film of said electrostatic adsorption means in a round term of a pulse may become 1/2 or less [of said pulse bias voltage].
[Claim 19] The step which arranges a sample to one side of the electrode prepared in the vacuum processing room, and the step which holds this sample to said electrode by electrostatic adsorption power, The step which introduces raw gas into the ambient atmosphere by which said sample has been arranged, and the step which evacuates said ambient atmosphere in the processing pressure force of said sample, the step which plasma-izes said raw gas under said pressure, the step which processes this sample by said plasma, and the step which impresses pulse bias voltage to said sample -- since -- the plasma treatment approach characterized by becoming.
[Claim 20] The step which arranges a sample to one side of the electrode with which the pair whose gap is 10mm - 50mm counters, The step which holds the arranged this sample to said electrode by electrostatic adsorption power, The step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which decompresses said ambient atmosphere to 0.5-4.0Pa, and the step which impresses 10MHz - 500MHz high-frequency power, and plasma-izes said etching gas under said pressure, The plasma treatment approach characterized by consisting of a step which etches said sample

by this plasma, and a step which impresses pulse bias voltage at one [said] electrode at the time of this etching, and carrying out plasma treatment of the insulator layer in said sample.
[Claim 21] The step which arranges a sample to one side of the electrode prepared in the vacuum processing room, and the step which holds this sample to said electrode by electrostatic adsorption power, The step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which evacuates said ambient atmosphere, and the step which plasma-izes etching gas under said reduced pressure, It consists of a step which etches this sample by said plasma, and a step which impresses pulse bias voltage to said sample. The plasma treatment approach characterized by controlling the electrical-potential-difference change by the electrostatic adsorption film of said electrostatic adsorption means in a round term of the pulse at the time of said pulse bias voltage impression or less [of said pulse bias voltage] to 1/2.
[Claim 22] The step which arranges a sample to one electrode of the electrode which counters, and the step which holds the this arranged sample to said electrode by electrostatic adsorption power, The step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which plasma-izes the introduced this etching gas, and the step which etches said sample by this plasma, The plasma treatment approach characterized by consisting of a step which impresses the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 at the time of this etching, and carrying out plasma treatment of the insulator layer in said sample to one [said] electrode at it.
[Claim 23] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A bias impression means to impress bias voltage to said sample, and a radical supply means to have a means to decompose the gas for radical generating beforehand in said vacuum processing room, and to supply the radical of the amount of requests to it, Plasma treatment equipment characterized by providing a means to supply the gas for ion generating to said vacuum processing room, and a plasma production means to make said vacuum processing room generate the plasma, and using SiO2 as said sample.
[Claim 24] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A pulse bias impression means to impress pulse bias voltage to said sample, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, Plasma treatment equipment characterized by providing said plasma production means to supply the gas for ion generating and to generate the plasma in said vacuum processing room, and using SiO2 for it as said sample.
[Claim 25] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A pulse bias impression means to impress pulse bias voltage to said sample, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, While equipping said vacuum processing room with said plasma production means to supply the gas for ion generating and to generate the plasma and impressing the high-frequency voltage of 10MHz - 500MHz to it by said RF generator Plasma treatment equipment characterized by being constituted so that said vacuum processing room may be decompressed to 0.5-4.0Pa.
[Claim 26] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, Said plasma production means to supply the gas for ion generating to said vacuum processing room, and to generate the plasma, A pulse bias impression means to connect with said sample base and to impress pulse bias voltage to this sample base, Plasma treatment equipment characterized by providing an electrical-potential-difference control means to control the rise of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means.

[Claim 27] A vacuum processing room and the sample base for arranging the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to hold said sample on said sample base by electrostatic adsorption power including the electrostatic adsorption film which is plasma treatment equipment which has a plasma production means, and was prepared in said sample base, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, Said plasma production means to supply the gas for ion generating to said vacuum processing room, and to generate the plasma, A pulse bias impression means to connect with said sample base and to impress pulse bias voltage to this sample base, An electrical-potential-difference control means to control the electrical potential difference produced among the both ends of said electrostatic adsorption film with impression of said pulse bias voltage is provided. This electrical-potential-difference control means Plasma treatment equipment characterized by controlling the electrical potential difference by the electrostatic adsorption film of said electrostatic adsorption means or less [of said pulse bias voltage] to 1/2.
[Claim 28] The step which while counters and arranges a sample to an electrode, and the step which holds the this arranged sample to said electrode by electrostatic adsorption power, The step at which said sample plasma-izes the gas for radical generating in the ambient atmosphere arranged and held beforehand, and supplies the radical of the amount of requests to it, The step which supplies the gas for ion generating to said ambient atmosphere, and the step which evacuates said ambient atmosphere to 0.5-4.0Pa, The step which plasma-izes the gas for ion generating which impressed the high-frequency voltage of 10MHz - 500MHz to said electrode which counters, and was supplied under said pressure, The plasma treatment approach characterized by consisting of a step which carries out etching processing of said sample by this plasma, and a step which impresses pulse bias voltage at one [said] electrode at the time of this etching processing, and using SiO2 as said sample.
[Claim 29] The step which arranges a sample to one side of the electrode prepared in the vacuum processing room, and the step which holds this sample to said electrode by electrostatic adsorption power, The step at which said sample plasma-izes the gas for radical generating in the ambient atmosphere arranged and held beforehand, and supplies the radical of the amount of requests to it, The step which supplies the gas for ion generating to said ambient atmosphere, and the step which plasma-izes the gas for ion generating which impressed the high-frequency voltage of 30MHz - 100MHz to said ambient atmosphere, and was supplied under said pressure, The plasma treatment approach characterized by consisting of a step which processes this sample by said plasma, and a step which impresses pulse bias voltage to said sample, and using SiO2 as said sample.
[Claim 30] The step which arranges a sample to one side of the electrode prepared in the vacuum processing room, and the step which holds this sample to said electrode by electrostatic adsorption power, The step at which said sample plasma-izes the gas for radical generating in the ambient atmosphere arranged and held beforehand, and supplies the radical of the amount of requests to it, The step which supplies the gas for ion generating to said ambient atmosphere, and the step which evacuates said ambient atmosphere in the processing pressure force of said sample, The step which plasma-izes the gas for ion generating supplied under said pressure, The plasma treatment approach characterized by consisting of a step which processes this sample by said plasma, and a step which impresses pulse bias voltage to said sample, and making it the electrical potential difference of said electrostatic adsorption means become 1/2 or less [of said pulse bias voltage].
[Claim 31] The step which arranges a sample to one side of the electrode which was prepared in the vacuum processing room, and which counters, The step which holds this sample to said electrode by electrostatic adsorption power, and the step at which said sample plasma-izes the gas for radical generating in the ambient atmosphere arranged and held beforehand, and supplies the radical of the amount of requests to it, The step which supplies the gas for ion generating to said ambient atmosphere, and the step which evacuates said ambient atmosphere to 0.5-4.0Pa, The step which plasma-izes the gas for ion generating which impressed the high-frequency voltage of 30MHz - 100MHz to inter-electrode [said / which counters], and was supplied under said pressure, The plasma treatment approach characterized by consisting of a step which processes this sample by said plasma, and a step which impresses pulse bias voltage to said sample.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to suitable plasma treatment equipment to start plasma treatment equipment and an art, especially form the detailed pattern in a semi-conductor production process, and the plasma treatment approach.
[0002]
[Description of the Prior Art] As for plasma treatment, improvement in micro-processing nature or processing speed has been increasingly required with high integration of a semiconductor device. In order to meet this demand, low-voltage-izing of processing gas pressure and the densification of the plasma are needed.
[0003] There are some (it abbreviates to ICP) which a coil is excited [some] according to the power source of the thing using the cyclotron-resonance phenomenon (it abbreviates to ECR) of (1) microwave (2.45GHz) electromagnetic field and a static magnetic field (875G) and (2) RF frequency as what aims at low-voltage-izing of processing gas pressure and densification, generate induction field, and generate the plasma.
[0004] By the way, when etching the film of an oxide film system using fluorocarbon system gas, the present condition is that it is difficult for dissociation of gas to progress too much and to make high the selection ratio to the substrate (Si and SiN) of the oxide film system film by the ICP method shown in ECR shown above (1) or (2).
[0005] The conventional method of impressing the electrical potential difference of RF frequency between parallel plates, and on the other hand, generating the plasma is difficult for making stability discharge by the pressure of 10Pa or less. As [showed / in (3) JP,7-297175,A or JP,3-204925,A / as this cure] The 2 cycle exciting method for making an electrical potential difference with a high frequency of dozens of MHz or more generate the plasma, and performing bias control of a sample on the low frequency of several MHz or less, (4) -- the magnetron RIE (it abbreviates to M-RIE) which Field B was added in the direction which intersects the auto-bias electric field (E) by which induction was carried out to the sample front face as shown in JP,2-312231,A, and the electron by the electronic Lorentz force shut up, and used the operation -- there is law.
[0006] Moreover, there are some which were indicated by JP,56-13480,A as an approach of making a plasma consistency increasing to the bottom of low gas pressure. This utilizes the electron cyclotron resonance (ECR) by the microwave (2.45GHz) and static magnetic field (875Gauss) which are an electromagnetic wave, and a plasma consistency even with the high low gas pressure of 0.1-1Pa is obtained.
[0007] The processor equipped with the RF generator for accelerating the ion in the plasma and the electrostatic adsorption film which makes a sample hold on a sample base by electrostatic adsorption power on the other hand to the sample base which arranges a processed material (for example, it abbreviates to a semi-conductor wafer substrate and a following sample.) in the technical field which performs etching processing, membrane formation processing, etc. of a semi-conductor using the plasma is adopted.
[0008] For example, the equipment indicated by the USP No. 5,320,982 specification controls the ion energy which connects this power source to a sample base by using the RF generator of a sinusoidal output as bias power supply, and carries out incidence to a sample, making heat transfer gas intervene between a sample and a sample base, and performing temperature control of a sample, while generating the plasma with microwave and making a sample hold on a sample base by electrostatic adsorption power.

[0009] Moreover, it is indicated that it becomes possible to be able to narrow distribution width of face of the ion energy which carries out incidence to a sample by generating the ion control bias wave of the shape of a pulse which fixed-izes plasma inter-electrode field strength, and being impressed by the sample base, and to raise the processing dimensional accuracy of etching and the etching velocity ratio of the processed film and substrate material several times in JP,62-280378,A.
[0010] Moreover, it is indicated by JP,6-61182,A that generate the plasma using a electron cyclotron resonance, and pulse duty impresses the pulse bias of about 0.1% or more of width of face, and prevents generating of a notch in a sample.
[0011] In addition, the thing of a publication is in Jap.J.Appl.phys, Vol.28, No.10, October, 1989, and PP.L 1860-L 1862 as an example as for which cyclotron resonance raises a lifting and a plasma consistency by the VHF electrification magnetic wave and the static magnetic field. However, a 144MHz RF is impressed to the central conductor of a coaxial configuration by this example, the magnetic field of 51G parallel to a central conductor is added, cyclotron resonance is produced, PURAZU of high density is generated, and the sample base grounded to the lower stream of a river of this plasma generating section is installed.
[0012]
[Problem(s) to be Solved by the Invention] A plasma generating method given in JP,7-288195,A or JP,7-297175,A generates the plasma by the RF (13.56MHz and dozens of MHz) among the above-mentioned conventional technique. Etching of an oxide film can be made to generate the good plasma in the gas pressure of dozens-5Pa (pascal) extent. However, with detailed-izing with a pattern dimension of about 0.2 micrometers or less, perpendicular-ization of a processing configuration is required more strongly and, for that, the fall of gas pressure is becoming indispensable.
[0013] However, it is difficult to make stability generate the plasma of the consistency of the request of 5x1010cm ~ 3 or more about by 4Pa or less (0.4-4Pa) by the above-mentioned 2 cycle exciting method and the above-mentioned M-RIE method. For example, even if it makes the plasma excitation frequency high by the above-mentioned 2 cycle exciting method, it is difficult for reduction which a plasma consistency seldom increases above about 50MHz, or falls conversely to come out, and to carry out a plasma consistency with the low gas pressure of 0.4-4Pa more than 5x1010cm~3 </SUP>.
[0014] Moreover, the plasma consistency which the electron by the Lorentz force of the electron produced on a sample front face shuts up by the M-RIE method, and is generated by operation must be uniform all over a sample. However, generally a plasma consistency has the fault which the deviation within a field produces by the drift of ExB. Since it generates near the sheath near [where field strength is strong] the sample, the deviation of the plasma consistency which an electron shuts up in a sample front face directly, and is formed in an operation cannot be amended by approaches, such as diffusion.
[0015] uniform PURAZUMAGA profit **** which do not have a bias even if it adds 200 gauss as maximum of a magnetic field parallel to a sample by arranging a magnet so that magnetic field strength may become weak in the direction of a drift of the electron by ExB as indicated by JP,7-288195,A as this solution. However, since it will be limited to the specific narrow range with the conditions from which the plasma becomes uniform once it fixes magnetic-field-strength distribution, change of processing conditions has the fault which cannot follow in footsteps easily. Especially, in order for the pressure on a sample center section to become high ten percent or more from the pressure on a sample edge when narrow, and to avoid the differential pressure on a sample, when an inter-electrode distance is about 20mm or less to the diameter sample of macrostomia beyond phi300, and setting spacing between a sample base and a counterelectrode as 30mm or more, it is in the inclination especially whose difficulty increases.
[0016] Thus, by the above-mentioned 2 cycle exciting method and the above-mentioned M-RIE method, it is the low voltage of 0.4 to 4 Pa, and it is difficult to make the plasma consistency of 5x1010cm~3 into homogeneity in a phi300mm sample side. Therefore, by the 2 cycle exciting method or the M-RIE method, it is in a difficult situation for it to be uniform, and to have high-speed workability to the wafer of the diameter of macrostomia beyond phi300mm, and to process a selection ratio with substrates (Si, SiN, etc.) for processing below the diameter of 0.2 micron highly.
[0017] On the other hand, there are some which were indicated by JP,56-13480,A in the above-mentioned conventional technique as an approach to which the plasma consistency by low gas pressure is made to increase sharply. However, by this method, dissociation of gas progressed too much, and when silicon oxide, a nitride, etc. were etched using the gas containing a fluorine and carbon, a fluorine atom / molecule, and fluorine ion were generated so much, and there was a fault that a selection ratio with desired substrates (Si etc.) was not obtained. The ICP method using the induction field of RF power also had the fault to which dissociation progresses too much like the describing [above] ECR method.
[0018] Moreover, generally the configuration which exhausts raw gas from the circumference of a sample is

taken, in this case, the consistency of a sample center section was high, it became the inclination for the plasma consistency of a sample periphery to become low, and there was a fault by which the homogeneity of processing on the whole sample surface is spoiled. Although preparing an annular bank (focal ring) near the circumference of a sample, and stagnating a gas stream was performed in order to improve this fault, it had the fault to which a resultant adheres, it becomes a foreign matter generation source, and the yield falls to this bank.

[0019] On the other hand, in order that the ion which carries out incidence to a sample may carry out energy control, adding RF bias of a sine wave to the electrode which lays a sample is performed. Although several 100kHz - 13.56MHz was used as that frequency, since ion followed in footsteps of change of the electric field in a sheath, with this frequency band, the energy distribution of the ion which carries out incidence had become the double peak mold which has a peak by two by the side of low energy and high energy. Although the processing speed of the ion by the side of high energy was high, the damage was given to the sample, and when there is a fault with low processing speed and it was going to lose the damage, processing speed fell, and the ion by the side of low energy had the fault from which a damage poses a problem, when it was going to gather processing speed. On the other hand, although the energy distribution which carries out incidence approached the single peak together, the greater part of the energy was used for plasma production, and when RF bias frequency was made into the high value of about 50MHz or more, since the electrical potential difference which joins a sheath fell sharply, there was a fault to which it becomes difficult to control the energy of incidence ion independently.

[0020] Moreover, a pulse bias-power-supply method given in JP,62-280378,A or JP,6-61182,A among the above-mentioned conventional technique The examination in the case of impressing pulse bias to a sample between a sample base electrode and a sample using the dielectric layer for electrostatic adsorption is not made. Since the ion acceleration voltage impressed between the plasma and a sample front face by the increment in the electrical potential difference generated among the both ends of an electrostatic adsorption film with the inflow of the ion current will fall and ion energy distribution will spread, if it applies to an electrostatic adsorption method as it is, There was a fault which cannot cope with processing of the detailed pattern to need performing sufficient temperature control for a sample.

[0021] moreover , by the conventional sinusoidal output bias power supply method indicated by the USP No. 5,320,982 specification , if a frequency became high , since the impedance of the sheath section would approach the own impedance of plasma or would become less than [it] , the unnecessary plasma arose near the sheath near the sample by bias power supply , while no longer be use effective in an acceleration of an ion , plasma distribution also got worse , and there be a fault in which the controllability of the ion energy by bias power supply be lose .

[0022] The limit of the control is becoming clear as processing of a sample makes it detailed in plasma treatment further again, since the gas by which it serves as the ion source and a source of a radical conventionally although it is important to control the amount of ion, the amount of radicals, and a radical kind proper because of the improvement in the engine performance was made to flow into a processing room, the plasma was generated in the processing interior of a room and coincidence was made to generate ion and a radical.

[0023] Moreover, the means for applying to homogeneity the installation bias voltage of the bias power supply impressed to a sample base over the whole sample side surface etc. is not described by the example using the cyclotron resonance of Jap.J.Appl.phys described previously and VHF ** of 28 and 10. Moreover, it is difficult for the height of a processing room to be about 200mm or more, and for the configuration utilized for the surface reaction owner effect in a counterelectrode not to become, but to obtain a high selection ratio with this configuration.

[0024] The purpose of this invention has precise processing of the detailed pattern to the sample of the diameter of macrostomia in offering easy plasma treatment equipment and the plasma treatment approach by not advancing dissociation of gas too much but acquiring the uniform plasma with the diameter of macrostomia beyond phi300mm.

[0025] Other purposes of this invention are to offer the plasma treatment equipment which can perform homogeneity and high-speed processing, especially oxide-film processing over the whole surface of the sample of the diameter of macrostomia, and its art.

[0026] Other purposes of this invention are to offer the plasma treatment equipment and the plasma treatment approach which raised the selection ratio of plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.).

[0027] Other purposes of this invention are to offer the plasma treatment equipment and the plasma treatment approach which acquire narrow ion energy distribution, are stabilized and can improve the

selection ratio of plasma treatment with a sufficient controllability by the low damage.
[0028] Other purposes of this invention are to offer the plasma treatment equipment and the plasma treatment approach of improving temperature control nature by electrostatic adsorption of a sample, being stabilized with a sufficient precision and performing processing of the detailed pattern to need.
[0029] Other purposes of this invention are to offer the plasma treatment equipment which can control ion and a radical independently, and the plasma treatment approach.
[0030]
[Means for Solving the Problem] In the plasma treatment equipment with which the description of this invention has a vacuum processing room, the plasma production means containing the electrode of a pair, the sample base that has the sample installation side in which the sample by which it is processed in this vacuum processing interior of a room is laid, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the high-frequency power of VHF ** (30MHz thru/or 300MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator It has the magnetic field means forming which forms a static magnetic field or a low frequency magnetic field, and is in forming the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[0031] A plasma production means by which other descriptions of this invention contain a vacuum processing room and the electrode of a pair, In the plasma treatment equipment which has the sample base in which the sample processed in this vacuum processing interior of a room is laid while serving as one side of said electrode, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the VHF electrification force (50MHz thru/or 200MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator It has the magnetic field means forming which forms the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency magnetic field. The part used as the max of the component of a direction along the field of said sample base of said magnetic field sets up so that it may become said sample base and opposite side from the center of the electrode of said pair, and it is to form the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[0032] A plasma production means by which other descriptions of this invention contain a vacuum processing room and the electrode of a pair, In the plasma treatment approach of the sample by the plasma treatment equipment which has a sample base for arranging the sample processed in this vacuum processing interior of a room while serving as one side of said electrode, and a reduced pressure means to decompress said vacuum processing room By the step which decompresses said vacuum processing interior of a room with a reduced pressure means, and magnetic field means forming The step which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field in the direction which intersects the inter-electrode electric field of said pair, The VHF electrification force (30MHz thru/or 300MHz) is impressed to inter-electrode [of said pair] by the RF generator. Between the electrodes of said pair It is in having the step which forms the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator, and the step which processes said sample by the plasma by which ** Li generation is carried out at the cyclotron resonance of said electron.
[0033] In order that according to this invention dissociation of gas may not be advanced too much but saturation ion current distribution may acquire **5% or less of uniform plasma with the diameter of macrostomia beyond phi300mm, as an RF generator for plasma production, 30MHz cannot be found and 300MHz (50MHz thru/or 200MHz) of VHF is used preferably. A static magnetic field or a low frequency magnetic field is formed in the direction which, on the other hand, intersects the electric field produced in inter-electrode [of a pair] by said RF generator. Thereby, with a sample base, the cyclotron-resonance field of the electron by the interaction of a magnetic field and electric field is formed in the opposite side rather than the center of the electrode of this pair along the sample installation side of a sample base inter-electrode [of a pair]. A sample is processed to the cyclotron resonance of this electron by the plasma by which ** Li generation is carried out.
[0034] A magnetic field has the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency (1kHz or less) magnetic field preferably 10 gauss or more 110 gauss or less, and gas is made into the low voltage of 0.4Pa thru/or 4Pa. Moreover, there is no 30 and distance between two electrodes is preferably set to 30 thru/or 60mm 100mm. In addition, it cannot be overemphasized that the electrode of a pair is what has the area more than the area of the sample processed, respectively.

[0035] As a frequency f of an RF generator, by using 50 MHz<=f<=200MHz VHF, a plasma consistency does not have a single figure compared with the case of microwave ECR, and falls about double figures. Moreover, dissociation of gas also falls and unnecessary fluorine atom / molecule, and generating of ion also fall about single or more figures. Three or more [5x1010cm ~] processings of low-pressure and a high rate which the plasma with a high consistency is acquired moderately and are 0.4 to 4 Pa are attained as an absolute value of a plasma consistency the frequency of this VHF band, and by using cyclotron resonance. Furthermore, in order that dissociation of gas may not progress too much, either, a selection ratio with substrates, such as Si and SiN, is not worsened greatly.
[0036] Although dissociation of gas will progress for a while if compared with the 13.56MHz conventional parallel plate electrode, the fluorine atom / molecule by this, and the slight increment in ion can improve by installing the matter which contains silicon and carbon in an electrode surface or a chamber wall surface, or combining and discharging hydrogen and a fluorine further using adding bias to these, and the gas containing hydrogen.
[0037] Moreover, according to this invention, the part which serves as max of a magnetic field component parallel to a sample base between two electrodes is set as a sample base and the opposite side rather than the center of two electrodes. By making preferably magnetic field strength parallel to the sample in respect of sample installation of a sample base into 15 gauss or less 30 gauss or less The Lorentz force (ExB) committed into an electron near a sample installation side can be made into a small value, and generating of the heterogeneity of the plasma consistency by the electronic drift condenser by the Lorentz force in respect of sample installation can be abolished.
[0038] According to other descriptions of this invention, compared with near the center section of the sample, the electronic cyclotron-resonance effectiveness is enlarged on a periphery or its outside compared with a center so that generation of the plasma may be raised a periphery or near [its] an outside a sample. It can attain by making distance of a cyclotron-resonance field and a sample far, losing a cyclotron-resonance field, or lessening the rectangular degree of a magnetic field and electric field as a means which lowers the electronic cyclotron-resonance effectiveness, etc.
[0039] Moreover, if the field gradient near cyclotron-resonance magnetic field BC is made sudden and an ECR resonance region is narrowed, the cyclotron-resonance effectiveness can be weakened. An ECR resonance region is Bc(1-a) <=B<=Bc (1+a). However, it becomes the range of the magnetic field strength B which becomes 0.05 <=a<=0.1.
[0040] In an ECR resonance region, in order that dissociation may progress, especially generation of ion prospers. On the other hand, dissociation does not progress compared with an ECR resonance region, but, as for fields other than an ECR resonance region, the direction of generation of a radical prospers. By adjusting the high-frequency power applied to the width of face and the up electrode of an ECR resonance region, generating of the suitable ion for processing of a sample and a radical can be controlled more nearly independently.
[0041] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, While having a pulse bias impression means to impress pulse bias voltage to said sample and impressing the high-frequency voltage of 10MHz - 500MHz as said RF generator, it is in having constituted so that said vacuum processing room might be decompressed to 0.5-4.0Pa.
[0042] A sample base for other descriptions of this invention to arrange the sample processed at a vacuum processing room and this vacuum processing room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, It connects with said sample base and is in having established a pulse bias impression means to impress pulse bias voltage to this sample base, and an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means.
[0043] The step which arranges a sample to one side of the electrode of the pair which counters with which other descriptions of this invention were prepared in the vacuum processing room, The step which holds this sample to said electrode by electrostatic adsorption power, and the step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which evacuates said ambient atmosphere to 0.5-4.0Pa, and the step which impresses the high-frequency voltage of 10MHz - 500MHz, and plasma-izes etching gas under said pressure, It is in the plasma treatment

approach which consists of a step which etches said sample by this plasma, and a step which impresses pulse bias voltage to one [said] electrode.

[0044] The step which arranges a sample to one electrode of the electrode with which other descriptions of this invention counter, The step which holds the arranged this sample to said electrode by electrostatic adsorption power, The step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which plasma-izes the introduced this etching gas, and the step which etches said sample by this plasma, It is in consisting of a step which impresses the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 at the time of this etching, and carrying out plasma treatment of the insulator layers in said sample (for example, SiO2, SiN, BPSG, etc.) to one [said] electrode at it.

[0045] According to other descriptions of this invention, by impressing the pulse-like bias power of a predetermined property to the sample base equipped with an electrostatic adsorption means to have a dielectric layer for electrostatic adsorption, temperature control nature of a sample is fully performed, it is stabilized and processing of the detailed pattern to need can be performed. That is, it has an electrostatic adsorption means to hold a sample on a sample base by electrostatic adsorption power, and a pulse bias impression means to connect with a sample base and to impress pulse bias voltage to this sample base, and duty of the forward direction pulse part adds 1/2 or less pulse bias to a sample through a capacitative element in a period in 0.2 - 2 microseconds.

[0046] Moreover, according to other descriptions of this invention, as an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of pulse bias voltage corresponding to the electrostatic adsorption capacity of an electrostatic adsorption means, electrical-potential-difference change which joins the both ends of a dielectric layer by electrostatic adsorption during a pulse round term constitutes so that it may become 1/2 or less [of the magnitude of pulse bias voltage]. Specifically make thin thickness of the electrostatic chuck film of the dielectric prepared in the front face of a lower electrode, or let a dielectric be an ingredient with large specific inductive capacity. Or the approach of controlling the rise of the electrical potential difference which shortens the period of pulse bias voltage and joins the both ends of a dielectric layer again may be adopted.

[0047] According to other descriptions of this invention, the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be raised by impressing the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 to one [said] electrode further again at the time of etching of a sample.

[0048] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A bias impression means to impress bias voltage to said sample, and a radical supply means to have a means to decompose the gas for radical generating beforehand in said vacuum processing room, and to supply the radical of the amount of requests to it, It is in providing a means to supply the gas for ion generating to said vacuum processing room, and a plasma production means to make said vacuum processing room generate the plasma, and using SiO2 as said sample.

[0049] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A pulse bias impression means to impress pulse bias voltage to said sample, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, While having said plasma production means to supply the gas for ion generating to said vacuum processing room, and to generate the plasma and impressing the high-frequency voltage of 10MHz - 500MHz to said RF generator, it is in being constituted so that said vacuum processing room may be decompressed to 0.5-4.0Pa.

[0050] According to other descriptions of this invention, by controlling the amount and the quality of ion and RAJIRARU independently and impressing the pulse-like bias power of a predetermined property to the sample base equipped with an electrostatic adsorption means to have a dielectric layer for electrostatic adsorption, temperature control nature of a sample is fully performed, it is stabilized and processing of the detailed pattern to need can be performed.

[0051] Furthermore, the amount and the quality of ion and RAJIRARU are controlled independently, narrow ion energy distribution is acquired, it can be stabilized and the selectivity of plasma treatment etc. can be

raised with a sufficient controllability.
[0052] Moreover, the amount and the quality of ion and RAJIRARU are controlled independently, and as an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of pulse bias voltage corresponding to the electrostatic adsorption capacity of an electrostatic adsorption means, electrical-potential-difference change which joins the both ends of a dielectric layer by electrostatic adsorption during a pulse round term constitutes so that it may become 1/2 or less [of the magnitude of pulse bias voltage]. Specifically make thin thickness of the electrostatic chuck film of the dielectric prepared in the front face of a lower electrode, or let a dielectric be an ingredient with large specific inductive capacity. Or the approach of controlling the rise of the electrical potential difference which shortens the period of pulse bias voltage and joins the both ends of a dielectric layer again may be adopted.
[0053] Moreover, according to other descriptions of this invention, the selectivity of plasma treatment with the substrate over the insulator layers in a sample (for example, SiO_2, SiN, BPSG, etc.) etc. can be raised by controlling the amount and the quality of ion and RAJIRARU independently and impressing the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 in one [said] electrode at the time of etching of a sample.
[0054] Furthermore, according to other descriptions of this invention, the amount and the quality of ion and RAJIRARU are controlled independently and gas pressure of the processing interior of a room is made into the low voltage of 0.5-4.0Pa, using the high-frequency voltage of 10MHz - 500MHz as an RF generator for plasma generating. Thereby, the stable plasma is acquired. Moreover, by using such high-frequency voltage, ionization of the gas plasma becomes good and the selection-ratio control at the time of sample processing becomes good.
[0055]
[Embodiment of the Invention] The example of this invention is explained below. The first example which applied this invention to the plasma etching system of a counterelectrode mold at drawing 1 is shown first. In drawing 1 , the processing room 10 as a vacuum housing is equipped with the electrode with which the pair which consists of the up electrode 12 and the lower electrode 15 counters. A sample 40 is laid in the lower electrode 15. In order to **** the differential pressure on the sample side when processing the sample of the diameter of macrostomia beyond phi300mm to ten or less percent, as for the gap of two electrodes 12 and 15, it is desirable to be referred to as 30mm or more. Moreover, in order to reduce a fluorine atom, a molecule, and ion, it is desirable to set preferably the reaction on the upper part / lower electrode surface to 60mm or less 100mm or less from a viewpoint utilized effectively. RF generator 16 which supplies radio-frequency energy through a matching box 162 is connected to the up electrode 12. 161 is a source of an RF generator modulating signal. Between the up electrode 12 and the ground, the filter 165 which serves as low impedance to the frequency component of bias power supply 17, and serves as a high impedance to the frequency component of RF generator 16 is connected.
[0056] Surface area of the up electrode 12 installed almost in parallel with a sample base is made larger than the area of the sample 40 processed, and it is constituted so that an electrical potential difference may join homogeneity efficiently in the sheath on a sample side by impression of bias power supply 17.
[0057] The up electrode covering 30 as a removal plate of the fluorine which consists of silicon, carbon, or SiC is formed in the bottom front face of the up electrode 12. Moreover, the gas induction room 34 equipped with the gaseous diffusion plate 32 which diffuses gas in desired distribution is established in the upper part of the up electrode 12. Gas required for processing of etching of a sample etc. is supplied to the processing room 10 through the hole 38 prepared in the gaseous diffusion plate 32, the up electrode 12, and the up electrode covering 30 of the gas induction room 34 from the gas supply section 36. Evacuation of the outside room 11 is carried out by the vacuum pump 18 connected to the outside room through the bulb 14, and the processing room 10 is adjusted to the processing pressure force of a sample. 13 is an insulator. While raising a plasma consistency, in order to attain homogenization of the reaction in a processing room, the ring 37 for [discharge ******] is formed in the perimeter of the processing room 10. Between ** for exhaust air is established in the ring 37 for [discharge ******].
[0058] On the up electrode 12, it intersects perpendicularly with the electric field E formed in inter-electrode, and the magnetic field means forming 200 for forming a magnetic field parallel to the field of a sample 40 is established. the magnetic field means forming 200 -- a core 201 and electromagnetism -- the coil 202 and the insulator 203 are provided. As a component of the up electrode 12, there is a nonmagnetic material conductor, for example, aluminum and an aluminium alloy. As a component of the processing room 10, there are nonmagnetic material, for example, aluminum and an aluminium alloy, an alumina, a quartz, SiC, etc. The core 201 has the axial symmetry-of-revolution structure of a cross-section abbreviation easy

mold of having the core sections 201A and 201B that the field B to which magnetic flux is extended from the central upper part of the processing room 10 to abbreviation parallel along with the up electrode 12 toward the up electrode 12 at a periphery should be formed. The magnetic field formed between two electrodes of the magnetic field means forming 200 has the part which produces the cyclotron resonance of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency magnetic field (1 or less KHZ) preferably 110 gauss or less more than 10 gauss (Gauss).

[0059] The magnetic field strength Bc (gauss) which produces cyclotron resonance has the relation of Bc=0.357xf (MHz) to the frequency f of the RF for plasma production (MHz) a well-known passage.

[0060] In addition, as long as two electrodes 12 and 15 in this invention have the substantially parallel electrode of the pair which carries out phase opposite, it is good and electrodes 12 and 15 may have some concave surface or convex from the demand of a plasma production property etc. In such 2 electrode molds, inter-electrode electric-field distribution can be equalized easily, and making generation of the plasma by cyclotron resonance into homogeneity has the comparatively easy description by improving the homogeneity of the magnetic field which intersects perpendicularly with this electric field.

[0061] The lower electrode 15 which carries out installation maintenance of the sample 40 has composition equipped with the electrostatic chuck 20 of 2 pole type. That is, the lower electrode 15 is constituted by outside 1st lower electrode 15A and 2nd lower electrode 15B arranged through an insulator 21 in the inside upper part, and the dielectric layer 22 for electrostatic adsorption (it is hereafter called an electrostatic adsorption film for short) is formed in the upper front face of the 1st and the 2nd car lower electrode. DC power supply 23 are connected to the 1st and the 2nd car lower inter-electrode one through the coils 24A and 24B for a high frequency component cut, and as the 2nd lower electrode 15B side just becomes, it impresses direct current voltage to both lower inter-electrode one. Thereby, according to the Coulomb force which acts on a sample 40 and both lower inter-electrode one through the electrostatic adsorption film 22, on the lower electrode 15, it adsorbs and a sample 40 is held. As an electrostatic adsorption film 22, dielectrics, such as what mixed the titanic-acid ghost, can be used for an aluminum oxide and an aluminum oxide, for example. Moreover, as a power source 23, the DC power supply of several 100 V are used.

[0062] Moreover, the pulse bias power supply 17 which supplies the pulse bias of the amplitude of 20V-1000V is connected to the lower electrode 15 (15A, 15B) through the blocking capacitors 19A and 19B which cut DC component, respectively.

[0063] Although explained until now, using 2 pole type as an electrostatic chuck, other electrostatic chucks, for example, a unipolar system and n pole type (n>=3), of a method are sufficient.

[0064] When performing etching processing, the sample 40 which is the object of processing is laid on the lower electrode 15 of the processing room 10, and is adsorbed by the electrostatic chuck 20. On the other hand, gas required for etching processing of a sample 40 is supplied to the processing room 10 through the gas induction room 34 from the gas supply section 36. Evacuation of the outside room 11 is carried out by the vacuum pump 18, and it is evacuated so that the processing room 10 may become the processing pressure force of a sample, for example, 0.4-4.0Pa, (pascal). Next, from RF generator 16, 50MHz - 200MHz high-frequency power is outputted desirably, and 30MHz - 300MHz of raw gas of the processing room 10 is plasma-ized.

[0065] Electronic cyclotron resonance is produced between the up electrode 12 and the lower electrode 15, it is 0.4-4.0Pa in low gas pressure, and the plasma of a high consistency is made to generate in this case by 30 thru/or 300MHz high-frequency power, and the part of the static magnetic field 10 gauss or more 110 gauss or less formed of the magnetic field means forming 200.

[0066] On the other hand, a period impresses the bias of 0.05-0.4 to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds on electrical potential differences 20V-1000V from the pulse bias power supply 17, the duty of a pulse part forward in 0.2 microseconds - 5 microseconds controls the electron and ion in the plasma, and etching processing to a sample 40 is performed.

[0067] After etching gas is made desired distribution with the gaseous diffusion plate 32, it is poured into the processing room 10 through the hole 38 which ended to the up electrode 12 and the up electrode covering 30.

[0068] Moreover, using the thing containing carbon, silicon, or these, a fluorine and an oxygen component are removed to the up electrode covering 30, and a selection ratio with the substrate of a resist, silicon, etc. is raised to it.

[0069] In order to raise the micro-processing nature of the sample of the diameter of macrostomia, it is good to attain stabilization of discharge in a low-gas-pressure field using the thing of the higher frequency as RF generator 16 for plasma generating. In this invention, it is the plasma consistency of 5x1010 thru/or

5x1011cm~3 by low voltage gas (0.4Pa thru/or 4Pa), and in order not to advance dissociation of gas too much but to acquire the uniform plasma with the diameter of macrostomia, RF generator 16 for plasma production is connected to the up electrode 12. On the other hand, the bias power supply 17 for ion energy control is connected to the lower electrode 15 which laid the sample, and distance between these two electrodes is set to 30 thru/or 100mm.
[0070] Moreover, 300MHz of electronic cyclotron resonance is preferably produced between the up electrode 12 and the lower electrode 15 10 gauss or more 110 gauss or less as RF generator 16 for plasma production by the interaction with the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency (1kHz or less) magnetic field, 30MHz not being found and using VHF (50MHz thru/or 200MHz).
[0071] An example of the change of a plasma consistency when changing the frequency of the RF generator which generates the plasma, where the magnetic field which produces electronic cyclotron resonance is added to drawing 2 is shown. The pressure of the thing and processing room where sample offering gas added C4F8 to the argon 2 to 10% is 1Pa. The plasma consistency set the case of f= 2450MHz microwave ECR to 1, and has reference-value-ized it. In addition, the broken line shows the case where he has no magnetic field.
[0072] In 50 MHz<=f<=200MHz, a plasma consistency does not have about single figure compared with the case of microwave ECR, and falls about double figures. Moreover, dissociation of gas also falls and unnecessary fluorine atom / molecule, and generating of ion also fall single or more figures. Three or more [5x1010cm ~] processings of low-pressure and a high rate which the plasma with a high consistency is acquired moderately and are 0.4 to 4 Pa are attained as an absolute value of a plasma consistency the frequency of this VHF band, and by using cyclotron resonance. Furthermore, in order that dissociation of gas may not progress too much, either, a selection ratio with substrates, such as Si and SiN, is not greatly worsened to the insulator layer of SiO2 grade.
[0073] In 50 MHz<=f<=200MHz, although dissociation of gas progresses for a while compared with the 13.56MHz conventional parallel plate electrode, the fluorine atom / molecule by this, and the slight increment in ion can install the matter which contains silicon and carbon in an electrode surface or a chamber wall surface, and can improve. Or further, by adding bias to this electrode surface and chamber wall surface, a fluorine can be combined with carbon or silicon and can be discharged, or hydrogen and a fluorine are combined using the gas containing hydrogen, and it can discharge and improve.
[0074] If 200MHz or more of frequencies of an RF generator is set especially to 300MHz or more, a plasma consistency will become high, but since dissociation of gas becomes excessive, the increment in a fluorine atom / molecule, or ion becomes large too much and a selection ratio with substrates, such as Si and SiN, is worsened greatly, it is not desirable.
[0075] An electron shows the energy gain k acquired from RF electric field to drawing 3 at the time of cyclotron resonance and no resonating. Energy which an electron obtains in 1 period of a RF at the time of a non-magnetic field is set to e0, and it is a cyclotron-resonance magnetic field. Energy which an electron obtains in 1 period of a RF when Bc=2pif- (m/e) is impressed When referred to as e1, e1 and e0 become like several 1.
[0076]
[Equation 1]

$$e_0 = \frac{e^2 E^2}{2m}\left(\frac{\nu}{\omega^2+\nu^2}\right)$$

$$e_1 = \frac{e^2 E^2 D}{4m}\left(\frac{1}{\nu^2+(\omega-\omega c)^2}+\frac{1}{\nu^2+(\omega+\omega c)^2}\right) \cdots\cdots \text{数 } 1$$

但し、Eは電界強度

[0077] k is expressed with a degree type when these ratios (= e1/e0) are set to k. However, m:mass of electrons, e:electronic charge, f: Impression frequency K= (nu2+omega2) (1/2) [1/(nu2+(omega-omegac) 2)+(1/(nu2+(omega+omegac) 2))]
However, nu: Collision frequency omega[omega:excitation angular frequency and] c: The value of k becomes so large that a frequency is so high that gas pressure is low at general cyclotron angular frequency. Drawing 3 is the case of Ar (argon) gas, and is set to k>=150 by f>=50MHz in the pressure of P= 1Pa, and dissociation is promoted under low gas pressure compared with the time of there being no magnetic field. The cyclotron-resonance effectiveness becomes small quickly on the frequency of about

20MHz or less in the pressure of P= 1Pa. On the frequency of 30MHz or less, there are few cases where he has no magnetic field, and differences, and the cyclotron-resonance effectiveness is small so that it may understand also in the property shown in drawing 2 .

[0078] In addition, although the cyclotron-resonance effectiveness will increase if gas pressure is made low, in 1Pa or less, the electron temperature of the plasma increases and the opposite effect that dissociation progresses too much becomes large. In order to suppress too much dissociation of gas and to make a plasma consistency into about [5x1010cm ~ / 3 or more], 4Pa for about 1 to 4Pa is preferably good from 0.4Pa as a pressure of gas.

[0079] In order to demonstrate the cyclotron-resonance effectiveness, it is necessary to make the value of k or more into dozens. In order to use the cyclotron-resonance effectiveness effectively, without advancing dissociation of gas too much so that clearly also from drawing 2 or drawing 3 , by the pressure of 0.4Pa thru/or 4Pa, as an RF generator for plasma production, gas pressure does not have 30 and needs to use preferably 300MHz of 50 thru/or 200MHz VHF.

[0080] Drawing 4 shows variation deltaV of the ion acceleration voltage VDC by which induction is carried out to the sample when impressing 68MHz high-frequency power, and the induced voltage VDC in a sample while it grounds an up electrode by the conventional magnetron method chamber and gives the field B of a uniform longitudinal direction on a lower electrode. If the reinforcement of a magnetic field B is raised, the ion acceleration voltage VDC will become small according to the Lorentz force committed into an electron, and a plasma consistency will increase. However, in the case of the conventional magnetron discharge mold, since the reinforcement of a magnetic field B is as large as about 200 gauss, the homogeneity within the field of a plasma consistency gets worse, variation deltaV of induced voltage becomes large, and there is a fault in which the damage of a sample increases.

[0081] In order to make deltaV into or less 1 / five to 1/10 from drawing 4 compared with the case of 200 gauss of the conventional magnetron discharge mold, the reinforcement of a magnetic field B is [from / when it loses a damage in near a sample side that the small value of 15 gauss or less costs 30 gauss or less preferably] desirable.

[0082] A cyclotron-resonance field is the middle of the up electrode 12 and the lower electrode 15, and is formed in a mist and up electrode side from the mid-position of two electrodes. An axis of abscissa shows the distance from the sample side (lower electrode 15) to the up electrode 12, and, as for drawing 5 , the axis of ordinate shows the magnetic field. The examples of drawing 5 are conditions (impression frequency f1=100MHz, Bc=37.5G, and electrode spacing =50mm), and the ECR field is formed near 30mm from the sample side.

[0083] Thus, in this invention, the part which serves as max of a magnetic field component parallel to the lower electrode 15 (sample installation side) between the up electrode 12 and the lower electrode 15 is set to an up electrode surface or upper part [middle / of two electrodes] electrode side. By this, magnetic field strength parallel to the sample in a lower electrode surface is preferably made into 15 gauss or less 30 gauss or less, low RENTSUKA (ExB) which works into an electron near a lower electrode surface can be made into a small value, and generating of the heterogeneity within the field of the plasma consistency by the electronic drift condenser by low RENTSUKA in a lower electrode surface can be abolished.

[0084] According to the magnetic field means forming 200 of the example of drawing 1 , as shown in drawing 6 , an ECR field is formed in the location of the almost same height from the lower electrode 15 (sample installation side) except for near the center section of the sample. Therefore, uniform plasma treatment can be performed to the sample of the diameter of macrostomia. However, near the core of a sample, the ECR field is formed in the high location from the sample installation side. Since there is distance of 30mm or more between an ECR field and a sample base and ion and a radical trial are diffused and equalized between them, there is no problem in the usual plasma treatment. However, in order to carry out plasma treatment of the whole surface of a sample to homogeneity, it is desirable to be formed so that an ECR field may continue all over a sample and the ECR field of the outside of the location of the same height or a sample may become close to a sample base side a little rather than the ECR field near a core from a sample side. This cure is stated to a detail later.

[0085] As stated above, since dissociation of gas is advanced by the electron cyclotron resonance, using 30 thru/or 300MHz high-frequency power as RF generator 16 for plasma generating, in the example of this invention shown in drawing 1 , the plasma to which the gas pressure in the processing room 10 was stabilized by even the bottom of low voltage of 0.4Pa thru/or 4Pa is acquired. Moreover, since the collision of the ion in the inside of a sheath decreases, on the occasion of processing of a sample 40, the directivity of ion can increase and perpendicular micro-processing nature can be raised.

[0086] The perimeter of the processing room 10 makes min adhesion of the unnecessary deposit object to

the part outside the ring 37 for [discharge ******] while aiming at improvement in ** and a plasma consistency to make the sample 40 neighborhood localize the plasma with the ring 37 for [discharge ******].
[0087] In addition, as a ring 37 for [discharge ******], semi-conductors and electric conduction material, such as carbon, silicon, or SiC, are used. If this ring 37 for [discharge ******] is connected to an RF generator and the spatter by ion is produced, while reducing depository adhesion to a ring 37, the removal effectiveness of a fluorine can also be given.
[0088] In addition, since a fluorine can be removed when performing plasma treatment using the gas which contains a fluorine for the insulator layer of SiO2 grade if the susceptor covering 39 containing carbon, silicon, or these is formed on the insulator 13 of the circumference of a sample 40, it is useful to improvement in a selection ratio. In this case, if thickness of the insulator 13 for the lower part of the susceptor covering 39 is made thin to 0.5mm - about 5mm so that a part of power of bias power supply 17 may be impressed to the susceptor covering 39, the above-mentioned effectiveness will be promoted by the spatter effectiveness by ion.
[0089] Moreover, on both sides of the electrostatic adsorption film 22 of a dielectric, an electrostatic adsorption circuit is formed through the lower electrode 15 (15A, 15B) and a sample 40 of the potential of DC power supply 23. In this condition, according to electrostatic force, a sample 40 is stopped by the lower electrode 15 and held. Heat-conduction gas, such as helium, nitrogen, and an argon, is supplied to the rear face of the sample 40 stopped according to electrostatic force. Although the crevice of the lower electrode 15 is filled up with heat-conduction gas, the pressure is made into about thousands of pascals from hundreds of pascals. In addition, most electrostatic adsorption power is zero between the crevices in which the gap was prepared, and it can be considered that electrostatic adsorption power has occurred only in the heights of the lower electrode 15. However, since an electrical potential difference can be appropriately set as DC power supply 23 and the adsorption power which can bear the pressure of heat-conduction gas enough can be set up so that it may state later, a sample 40 moves by heat-conduction gas, or it is not flown.
[0090] By the way, the electrostatic adsorption film 22 acts so that a bias operation of the pulse bias to the ion in the plasma may be reduced. It is not actualizing, although this operation is produced also by the conventional approach which is carrying out bias using the sinusoidal power source. However, on the pulse bias, since the description that ion ENEGI width of face is narrow falls victim, a problem becomes large.
[0091] In this invention, in order to control the rise of the electrical potential difference generated among the both ends of the electrostatic adsorption film 22 with impression of pulse bias and to heighten the effectiveness of pulse bias, one description is to have established the electrical-potential-difference control means.
[0092] It is good to constitute so that change (VCM) of the electrical potential difference in a round term of the bias voltage produced among the both ends of an electrostatic adsorption film with impression of pulse bias as an example of an electrical-potential-difference control means may become 1/2 or less [of the magnitude (****) of pulse bias voltage]. There is a method of increasing the electrostatic capacity of a dielectric by making thin thickness of the electrostatic adsorption film which specifically consists of a dielectric prepared in the front face of the lower electrode 15, or using a dielectric as an ingredient with a large dielectric constant.
[0093] Or there is also the approach of shortening the period of pulse bias voltage and controlling the rise of an electrical potential difference VCM as other electrical-potential-difference control means, again. Furthermore, the method of separating into another location, for example, electrode with a sample another [the electrode by which arrangement maintenance is carried out] which counters, or the third electrode prepared independently, and preparing an electrostatic adsorption circuit and a pulse bias voltage impression circuit is also considered.
[0094] Next, change (VCM) of an electrical potential difference and the relation of pulse bias voltage which are produced among the both ends of the electrostatic adsorption film in a pulse bias round term which should be brought about by the electrical-potential-difference control means in this invention are stated to a detail using drawing 7 - drawing 13 .
[0095] First, the desirable example of an output wave used in the pulse bias power supply 17 of this invention is shown in drawing 7 . Inside of drawing, pulse amplitude: vp, Pulse period:T0 and forward direction pulse width:T1 It carries out.
[0096] When the wave of drawing 7 (A) is impressed to a sample via a blocking capacitor and the dielectric layer for electrostatic adsorption (it is hereafter called an electrostatic adsorption film for short), the potential wave on the front face of a sample in the steady state in the condition of having generated the

plasma according to another power source is shown in drawing 7 (B).
however, wave-like dc-component electrical potential difference : floating potential [of the VDC plasma]: -- maximum electrical-potential-difference [in a round term of the electrical potential difference produced among the both ends of Vf electrostatic adsorption film]: -- it is referred to as VCM.
[0097] The inside of drawing 7 (B), and Vf The becoming part (I) I [used as a forward electrical potential difference] Is a part which has mainly drawn only the electron current, and it is Vf. A negative part is the part which has drawn the ion current, and Vf. A part is a part (Vf is usually severalV-about tenv) which an electron and ion hang and suit.
[0098] In addition, in explanation of drawing 7 (A) and future, the capacity of a blocking capacitor and the capacity by the insulator of the sample surface neighborhood assume that it is sufficiently large compared with the capacity (it is called electrostatic adsorption capacity for short below) by the electrostatic adsorption film. The value of VCM is expressed with the following formula (several 2).
[0099]
[Equation 2]

$$V_{CM} = \frac{q}{c} = \frac{i_i \times (T_0 - T_1)}{(\varepsilon_r \varepsilon_0 / d) \times K} \quad \cdots\cdots \text{数} 2$$

[0100] However, q: (T0-T1) The ion current consistency which flows into a sample at a period (average)
c: Electrostatic adsorption capacity per unit area (average)
ii : ion current consistency epsilonr : Specific inductive capacity d of an electrostatic adsorption film: Thickness of an electrostatic adsorption film epsilon 0 : Dielectric constant in a vacuum (constant)
K: Electrode coverage of an electrostatic adsorption film (<=1)
To drawing 8 and drawing 9 , pulse duty ratio: (T1/T0) is T0, while it is fixed. The potential wave on the front face of a sample at the time of making it change and the probability distribution of ion energy are shown. However, it is referred to as T01 and T02:T03:T04:T05=16:8:4:2:1.
[0101] As shown in (1) of drawing 8 , it is the pulse period T0. If too large, it separates from the potential wave on the front face of a sample greatly from a square wave, and it becomes a triangular wave, and as shown in drawing 9 , it becomes fixed distribution and is not desirable [ion energy] to the higher one from the lower one.
[0102] As shown in (2) - (5) of drawing 8 , it is the pulse period T0. (VCM/vp) serves as a value smaller than 1, and ion energy distribution also becomes narrow as it is made small.
[0103] drawing 8 and drawing 9 -- setting -- T0=T01, and TO02, T03, T04 and T -- 05= (VCM/vp) 1, 0.63, 0.31, and 0. -- 16 and 0.08 are supported. Next, the relation of the maximum electrical potential difference VCM in a round term of the electrical potential difference produced between the OFF (T0-T1) period of a pulse and the both ends of an electrostatic adsorption film is shown in drawing 10 .
[0104] When the coat of about 50% of an electrode (K= 0.5) is carried out using a titanium oxide content alumina (epsilonr=10) with a thickness of 0.3mm as an electrostatic adsorption film, it is ion current consistency ii =5 mA/cm2. The thick wire (line of standard conditions) of drawing 10 shows the value change of VCM in the inside of the semi-gross density plasma.
[0105] The electrical potential difference VCM produced among the both ends of an electrostatic adsorption film as the OFF (T0-T1) period of a pulse becomes large so that clearly from drawing 10 is the pulse voltage vp which serves as a big value in proportion to it, and is usually used. It will become above.
[0106] For example, it sets to a plasma etching system and is usually by gate etching by selectivity with a damage, a substrate, or a mask, a configuration, etc. By 20volt <= vp <=100volt metal etching By 50volt <= vp <=200volt oxide film etching It is restricted to 250volt <= vp <=1000volt.
[0107] When it is going to fulfill the below-mentioned conditions of <=(VCM/vp) 0.5, in reference condition, the upper limit of (T0-T1) is as follows.
By gate etching (T0-T1) By <=0.15-microsecond metal etching (T0-T1) By <=0.35-microsecond oxide film etching (T0-T1) T0 is 0.1 microseconds at <=1.2microsecond and time. If it becomes near, since the impedance of an ion sheath will approach the impedance of the plasma or will become less than [it], while producing generating of the unnecessary plasma, bias power supply is no longer used effective in acceleration of ion. For this reason, since the controllability of the ion energy by bias power supply gets worse, T0 has 0.2 preferably good microseconds or more 0.1 microseconds or more.
[0108] Therefore, vp In the gate etcher pressed down low, withstand voltage is not reduced, and it is thin, for example, it necessary for specific inductive capacity to change the ingredient of an electrostatic adsorption film into 10-100, and a high thing (for it to be epsilonr =25 at Ta 2O3), or to set desirably 10 micrometers - 400 micrometers of thickness to 10 micrometers - 100 micrometers.

[0109] In drawing 10 , the value of VCM at the time of making the electrostatic capacity c per unit area increase by 2.5 times, 5 times, and 10 times, respectively was also written together. Even if it improves an electrostatic adsorption film, if the improvement which increases electrostatic capacity c several times is regarded as a limit and sets to VCM<=300 volt and c<=10c0, 0.1microsecond<=(T0-T1) <=10microsecond will come in the present condition. A part effective in plasma treatment is a part of (T0-T1) by acceleration of ion, and the smaller possible one as pulse duty (T1/T0) is desirable.
[0110] It is drawing 11 which was estimated by (VDC/vp) as effectiveness of plasma treatment which also considered the time average. It is desirable to make (T1/T0) small, and to enlarge (VDC/vp).
[0111] If 0.5 <= (VDC/vp) is assumed as effectiveness of plasma treatment and the below-mentioned conditions and <=(VCM/vp) 0.5 are put in, pulse DEYUDI will become about <=(T1/T0) 0.4.
[0112] In addition, although pulse DEYUDI (T1/T0) is so effective in control of ion energy that it is small, if it is made small beyond the need, pulse width T1 will serve as a small value which is about 0.05 microseconds, and separation with a high frequency component for plasma generating which comes to contain many dozens of MHz frequency components, and mentions them later also becomes difficult. As shown in drawing 11 , the falls of (VDC/vp) between 0 <=(T1/T0) <=0.05 are few, and especially a problem is not produced or more in 0.05 as (T1/T0).
[0113] Here shows the ion energy dependency of the etching rates ESi and ESiO2 of the silicon when plasma-izing chlorine gas 1.3Pa, and the oxide film of a substrate as an example of gate etching to drawing 12 . The etching rate ESi of silicon becomes constant value in low ion energy. Ion energy also increases ESi according to the increment in ion energy beyond about 10V. Ion energy is 0 or less about 20V, and if about 20V is exceeded, ESiO2 will increase the etching rate ESiO2 of the oxide film which serves as a substrate on the other hand with ion energy.
[0114] Consequently, the field where selection-ratio ESi/ESiO2 with a substrate becomes [ion energy] infinity or less about 20V exists. As for selection-ratio ESi/ESiO2 with a substrate, ion energy falls quickly with the increment in ion energy beyond about 20V.
[0115] ethyne great of an oxide film and silicon when drawing 13 plasma-izes C4F8 gas 1.0Pa as an example of etching of the oxide films (SiO2, BPSG, HISO, etc.) which are kinds of an insulator layer -- ion energy distribution of ESiO2 and ESi is shown.
[0116] In low ion energy, the etching rate ESiO2 of an oxide film serves as a negative value, and produces a depository. In the 400V neighborhood, ESiO2 just starts quickly and ion energy increases gradually after that. The etching rate ESi of the silicon which serves as a substrate on the other hand serves as (+) and (etching) from (-) and (etching), and increases from ESiO2 gradually in the high place of ion energy.
[0117] Consequently, the selection ratios ESiO2/ESi with a substrate in the neighborhood which changes from (-) to (+) infinity It becomes and ESiO2/ESi falls quickly with the increment in ion energy more than by it. [ESiO2]
[0118] To application in an actual process, in consideration of ESi, the value of ESiO2, ESi/ESiO2, and the magnitude of the value of ESiO2/ESi, bias power supply is adjusted and ion energy is made into a proper value by drawing 12 and drawing 13 .
[0119] Moreover, just etching (etching until the substrate film appears) gives priority to the magnitude of an etching rate, and just, if after dirty gives priority to the magnitude of a selection ratio and ion energy is just changed into dirty order, a still better property will be acquired.
[0120] By the way, the property shown in drawing 12 and drawing 13 is a property when the energy distribution of ion is limited to a narrow part. Since each etching rate when the energy distribution of ion is large serves as the time average value, it will not be able to be set as an optimum value but a selection ratio will fall sharply.
[0121] According to the experiment, when (VDC/vp) was or less 0.3 extent, the breadth of ion energy became about **15% or less, and 30 or more high selection ratios were obtained also in the property of drawing 12 or drawing 13 . Moreover, when it was <=(VDC/vp) 0.5, the improvement of a selection ratio etc. was able to be aimed at compared with the conventional sinusoidal bias method.
[0122] thus, as an electrical-potential-difference control means to suppress the electrical-potential-difference change (VCM) during a round term of the pulse voltage produced among the both ends of an electrostatic adsorption film That VCM constitutes so that it may become 1/2 or less [of the magnitude vp of pulse bias voltage] often and specifically The capacity of a dielectric can be increased by making thin thickness of the electrostatic chuck film 22 of the dielectric prepared in the front face of the lower electrode 15, or using a dielectric as an ingredient with a large dielectric constant. Or the period of pulse bias voltage is made it is desirable and as short as 0.2 microseconds - 5 microseconds (repeat frequency: correspond to 0.2MHz - 5MHz) for 0.1 microseconds to 10 microseconds, and electrical-potential-

difference change of the both ends of an electrostatic adsorption film is controlled for pulse DEYUDI (T1/T0) as 0.05 <=(T1/T0) <==0.4.

[0123] Or you may make it fulfill the conditions of <=(VCM/vp) 0.5 which change of the electrical potential difference VCM produced among the both ends of an electrostatic adsorption film described above again combining some of thickness of the electrostatic adsorption film of the above-mentioned dielectric, specific inductive capacity of a dielectric, and periods of pulse bias voltage.

[0124] Next, the example which used the vacuum processing room of drawing 1 for etching of insulator layers (for example, SiO2, SiN, BPSG, etc.) is described.

[0125] As gas, the thing of a presentation of CO:10 - 20%, is used C4F8:1-5%, Ar:90-95%, O2:0-5% or C4F8:1-5%, Ar:70-90%, and O2:0-5%. As RF generator 16 for plasma generating, stabilization of discharge in a 1-3Pa low-gas-pressure field is measured using a frequency higher than before, for example, a 40MHz thing.

[0126] In addition, when dissociation beyond the need advances by RF-ization of RF generator 16 for the sources of the plasma, the output of RF generator 16 is turned on and off or level modulation controlled by the source 161 of an RF generator modulating signal. At the time of a high level, generation of ion prospers compared with generation of a radical, and when it is a low, generation of a radical prospers compared with generation of ion. As ON (or high level at time of level modulation) time amount, 20 microseconds - about 150 microseconds of periods are used for 10 to 100 microseconds about 5 to 50 microseconds as off time amount (or low at the time of a level modulation). While this prevents unnecessary dissociation, a desired ion-radical ratio can be obtained.

[0127] Moreover, the modulation period of the RF generator for the sources of the plasma usually becomes long compared with the period of pulse bias. Then, the improvement of a selection ratio was completed by making the modulation period of the RF generator for the sources of the plasma into the integral multiple of the period of pulse bias, and optimizing the phase between two.

[0128] On the other hand, impression of pulse bias voltage performs the ion in the plasma, and ion energy is controlled acceleration and by making it put perpendicular ON in a sample. As pulse bias power supply 17, by using the power source of pulse amplitude:****=800V pulse period:T=0.65microsecond and pulse width:T1=0.15microsecond, the distribution width of face of ion energy became **15% or less, and the plasma treatment with the sufficient property of 20-50 as Si of a substrate or a selection ratio with SiN became possible.

[0129] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 14 is explained. Although this example is the same configuration, it differs from having been shown in drawing 1 in that the lower electrode 15 holding a sample 40 has composition equipped with the electrostatic chuck 20 of a unipolar system. The dielectric layer 22 for electrostatic adsorption is formed in the upper front face of the lower electrode 15, and the plus side of DC power supply 23 is connected to the lower electrode 15 through the coil 24 for a high frequency component cut. Moreover, the pulse bias power supply 17 which supplies the forward pulse bias of 20V-1000V is connected through the blocking capacitor 19.

[0130] While installing the rings 37A and 37B for [discharge ******] in the perimeter of the processing room 10 and aiming at improvement in a plasma consistency, adhesion of the unnecessary deposit object to the part besides ring 37for [discharge ******] A and 37B is made into min. In the rings 37A and 37B of drawing 14 for [discharge ******], the diameter of the soil hand part of ring 37A for [discharge ******] by the side of a lower electrode is made smaller than the diameter of the soil hand part of ring 37B for [discharge ******] by the side of an up electrode, and makes distribution of the resultant in the sample circumference uniform.

[0131] In addition, semi-conductors and conductors, such as carbon, silicon, or SiC, are used for the side which faces a processing room side at least as an ingredient of the rings 37A and 37B for [discharge ******]. Moreover, 100K-13.56MHz bias-power-supply 17A for discharge ****** rings is connected to lower electrode side ring 37A through capacitor 19A, it constitutes like, and while reducing depository adhesion to the rings 37A and 37B by the spatter effectiveness of ion for which a part of power of the high periphery power source 16 is impressed to up electrode side ring 37B, the removal effectiveness of a fluorine is also given.

[0132] In addition, 13A and 13C of drawing 14 are an insulator which consists of aluminas etc., and 13B is an insulator which has conductivity, such as SiC, glassy carbon, and Si.

[0133] when the conductivity of Rings 37A and 37B is low, conductors, such as a metal, are built in in ring 37A and 37B -- making -- the front face of a ring, and internal organs -- by narrowing distance of a conductor, high-frequency power can carry out that it is easy to emanate from the front face of Rings 37A

and 37B, and can heighten the spatter effectiveness.
[0134] As for the up electrode covering 30, only the circumference is usually fixed to the up electrode 12 with a bolt 250. Gas is supplied to the up electrode covering 30 through the gas induction room 34, the gaseous diffusion plate 32, and the up electrode 12 from the gas supply section 36. In order that the hole prepared in the up electrode covering 30 may make abnormality discharge in a hole hard to generate, it is the pore of the diameter of 0.3-1mm, and the gas pressure of the up electrode covering 30 upper part becomes several [of one atmospheric pressure / 1/] to about 1/10. For example, the force about 100kg or more is added as a whole to the up electrode covering 30 of the diameter of 300mm. For this reason, the up electrode covering 30 becomes convex to the up electrode 12, and produces a clearance hundreds of microns or more near a center section.
[0135] In this case, if about 30MHz or more of frequencies of the source 16 of high frequency becomes high, the phenomenon in which it becomes impossible to disregard longitudinal direction resistance of the up electrode covering 30, and the plasma consistency near a center section falls especially will come out. What is necessary is just to fix the up electrode covering 30 to the up electrode 12 by main approach other than the circumference, in order to improve this. In the example of drawing 14 , with the bolt 251 of insulators, such as semi-conductors, such as SiC and carbon, or an alumina, several places of the main approach of the up electrode covering 30 are fixed to the up electrode 12, and distribution of the RF impressed from the up electrode 12 side is made uniform.
[0136] In addition, the approach of the up electrode covering 30 which fixes a main approach part to the up electrode 12 at least is not limited to the above-mentioned bolt 251 at all, is the whole surface about the up electrode covering 30 and the up electrode 12 by the matter with an adhesion operation, or may be pasted up in the part of main approach at least.
[0137] In the example of drawing 14 , the sample 40 which is the object of processing is laid on the lower electrode 15, and is adsorbed according to the Coulomb force produced among the both ends of the electrostatic adsorption film 22 with the positive charge by the electrostatic chuck 20 23, i.e., DC power supply, and the negative charge supplied from the plasma.
[0138] An operation of this equipment evacuates the pressure of the processing room 10 to the processing pressure force of a sample, and 0.5-4.0Pa by carrying out evacuation with the another side vacuum pump 18, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing [are the same as that of the plasma etching system of 2 electrode molds shown in drawing 1 ,] raw gas into the processing room 10 by the predetermined flow rate from a gas supply system 36, when performing etching processing. Next, RF generator 16 is set to ON, between two electrodes 12 and 15, the high-frequency voltage of 30MHz - 100MHz is impressed preferably, and 20MHz - 500MHz of plasma is generated. On the other hand, 20V-1000V, and a period impress the forward pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds from the pulse bias power supply 17, the plasma in the processing room 10 is controlled, and etching processing is performed in a sample 40.
[0139] impression of such pulse bias voltage -- the ion in the plasma, or ion -- and -- and highly precise configuration control or selection-ratio control is performed for an electron in a sample acceleration and by making it put perpendicular ON. The property required for the pulse bias power supply 17 and the electrostatic adsorption film 22 is the same as that of the example of drawing 1 , and is omitted for details.
[0140] Next, drawing 15 thru/or drawing 17 explain other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 1 , the configurations of the magnetic field means forming 200 differ. Eccentricity of the core 201 of the magnetic field means forming 200 is carried out, and it is constituted so that it may drive by the motor 204 centering on the shaft equivalent to the center position of a sample 40 and may rotate at the rate of the number of per minute thru/or dozens rotations. In addition, the core 201 is grounded. In order to carry out plasma treatment of the whole surface of a sample with high precision, compared with near the center section of the sample, it is good to enlarge the electronic cyclotron-resonance effectiveness on a periphery or its outside compared with a center so that generation of the periphery of a sample or the plasma near [the] an outside may increase. However, in the case of the example of drawing 1 , as shown in drawing 6 , near the core of a sample, there is no ECR field and the case where a plasma consistency becomes low too much near a core comes out.
[0141] In the example of drawing 15 , when the core 201 the magnetic field means forming 200 carried out [the core] eccentricity rotates, distribution of a magnetic field changes, and near the core of a sample, an ECR field is formed in a low location from a sample side, and is formed in a location high from a sample side at time-of-day t=1/2T0 by time of day t= 0 and t=T0. As a result of a core's 201 rotating at the rate of the

number of per minute thru/or dozens rotations, as shown in drawing 17 , the average of the magnetic field strength of a direction parallel to the sample side in the pars intermedia of two electrodes turns into the almost same value by time average-ization by rotation. That is, an ECR field is formed in the location of the almost same height from a sample side except for the periphery of a sample.
[0142] In addition, as the alternate long and short dash line showed in the core 201 section of drawing 15 , the core which constitutes the magnetic circuit of the side near the core of the center section which carried out eccentricity is thin in the thickness, and if the core which constitutes the magnetic circuit of a far side thickens the thickness, the homogeneity of magnetic field strength will improve further.
[0143] Next, drawing 18 thru/or drawing 19 explain other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 15 , the configurations of the magnetic field means forming 200 differ. The core 201 of the magnetic field means forming 200 has concave edge 201A in the location corresponding to the center of a processing room, and has edge 201B besides the side location of a processing room. According to an operation of concave edge 201A, magnetic flux B has the inclined direction component. Consequently, distribution of a magnetic field changes, and as shown in drawing 19 , compared with the case where the magnetic field strength of a component parallel to a sample side is the example of drawing 1 , it is equalized more.
[0144] Next, drawing 20 explains other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 15 , the configurations of the magnetic field means forming 200 differ. The core 201 of the magnetic field means forming 200 is fixed, and constitutes a magnetic circuit with the core 205 arranged in the location corresponding to the center of a processing room. A core 205 rotates the surroundings of the shaft which passes along the core of edge 201A with an insulator 203. Of such a configuration, the average location of the ECR field in near the core of a sample is formed in the almost same location from a sample side like the example of drawing 15 . That is, an ECR field continues all over a sample and is formed in the location of the almost same height from a sample side.
[0145] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 21 thru/or drawing 22 is explained. The magnetic field means forming 200 equips the perimeter of the processing room 10 with two pairs of coils 210,220, and by changing the sense of the field which can be put on the coil of each set one by one like arrow heads 1, 2, 3, and 4, it consists of this example so that rotating magnetic field may be formed. Center position O-O of a coil 210,220 is located in the upper part [middle / of two electrodes 12 and 15] electrode 12 side. 30 gauss or less, this constitutes the magnetic field strength on a sample 40 so that it may become 15 gauss or less preferably. By selecting the location of a coil 210,220, and an outer diameter suitably, the intensity distribution of a magnetic field can be adjusted so that generation of the periphery of a sample or the plasma near [the] an outside may increase more.
[0146] Next, drawing 23 and drawing 24 explain the plasma etching system of 2 electrode molds which become other examples of this invention. In this example, it has coil 210' of the pair arranged in the shape of radii in a horizontal plane along the perimeter of the circular processing room 10 as magnetic field means forming 200. The current which flows to coil 210' of this pair is controlled, and as an arrow head (1) and (2) showed, the polarity of a magnetic field is changed to drawing 23 for every fixed period.
[0147] As a broken line shows to drawing 24 , since magnetic flux B spreads in a processing room core in a vertical plane, the magnetic field strength of a processing room core falls. However, since coil 210' of a pair is curved along a processing room, in a horizontal plane, magnetic flux B gathers in a processing room core. Therefore, the magnetic field strength of a processing room core can be raised compared with the example of drawing 22 . That is, in the example of drawing 23 , compared with the example of drawing 22 , the fall of the magnetic field strength in a processing room core can be controlled, and the homogeneity of the magnetic field strength in the sample installation side of a sample base can be raised.
[0148] Moreover, the drift condenser of ExB is lessened by changing the polarity of a magnetic field for every fixed period.
[0149] In addition, two pairs of the same coils as the example of drawing 22 may be adopted as magnetic field means forming 200.
[0150] moreover -- a magnetic field -- means forming -- 200 -- ****** -- circular -- a coil -- 210 -- ' -- replacing with -- drawing 25 -- being shown -- as -- being circular -- processing -- a room -- ten -- a perimeter -- meeting -- arranging -- having had -- plurality -- a straight line -- a coil -- a part -- combination -- becoming -- a convex -- type -- a coil -- 210 -- ' -- ****** -- being good . Also in this case, in a horizontal plane, magnetic flux B comes to gather in a processing room core, and the same effectiveness as the example of drawing 23 is acquired.

[0151] Furthermore, like the example of drawing 26 , the medial axis of one pair of coils is made to incline in a vertical plane, and may be arranged so that a sample side may be approached in a processing room core. Since according to this example the magnetic field strength of a processing room core can be raised and the magnetic field strength of a processing room periphery can be lowered, the homogeneity of the magnetic field strength in the sample installation side of a sample base can be raised. In addition, for equalization of magnetic field strength, it is good to make theta into the range of 5 times thru/or 25 degrees whenever [tilt-angle / of the medial axis of a coil].
[0152] Moreover, as shown in drawing 27 , by installing coil 210B and controlling the current of 2 sets of coils near the coil 210A of a pair, with an ECR resonance location, the inclination of the magnetic field near an ECR resonance location can be changed, and the width of face of an ECR resonance region can also be changed. By optimizing the width of face of an ECR resonance region for every process, it becomes possible to obtain the ion / radical ratio suitable for each process.
[0153] In addition, the homogeneity of magnetic-field-strength distribution and the control characteristic can be further raised by combining suitably the example of drawing 23 thru/or drawing 27 described above if needed.
[0154] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 28 thru/or drawing 29 is explained. In this example, while a part of processing interior wall consists of conductors, it is grounded. On the other hand, the magnetic field means forming 200 equips the perimeter and the upper part of the processing room 10 with the coil 230,240. As an arrow head shows, the sense of the magnetic flux B formed with a coil 230 and the sense of magnetic-flux B' formed with a coil 230 consist of denial **** and circumference ****** of the processing room 10 mutually in the core of the processing room 10 so that it may superimpose mutually. Consequently, the intensity distribution of the magnetic field on a sample side become like drawing 29 . And in a part for the installation surface part of a sample 40, the sense of the electric-field component between the up electrode 12 and the lower electrode 15 and the sense of a field component are parallel. On the other hand, in the lateral part of the installation side of a sample 40, it is the periphery of the up electrode 12, or the part of the up electrode 12 and a processing interior wall, and the field component of the lengthwise direction which intersects perpendicularly with a lateral electric-field component arises.
[0155] therefore, the example of drawing 28 -- getting twisted -- the cyclotron-resonance effectiveness of the electron in near the core of a sample can be lowered, and generation of the periphery of a sample or the plasma near [the] an outside can be raised. Thus, plasma density distribution can be equalized by raising more generation of the periphery of a sample, or the plasma near [the] an outside.
[0156] Next, drawing 30 explains other examples of this invention. this example impresses the high frequency f3 about 1MHz or less to the up electrode 12 as bias from the low frequency power source 163, when ion energy sufficient in the high-frequency power f1 impressed to the up electrode 12 is not obtained from RF generator 16 in the plasma etching system of 2 electrode molds shown in drawing 1 -- ion energy -- 100-200 -- it is made to increase about by V In addition, 164,165 is a filter.
[0157] Next, drawing 31 explains the example of this invention in the plasma etching system of 2 electrode molds of a non-magnetic field mold.
[0158] As stated above, in order to raise the micro-processing nature of a sample, it is good to measure stabilization of discharge in a low-gas-pressure field using the thing of the higher frequency as RF generator 16 for plasma generating. In the example of this invention, the processing pressure force of the sample in the processing room 10 is set to 0.5-4.0Pa. Since the collision of the ion in the inside of a sheath decreased by making gas pressure in the processing room 10 into the low voltage of 40 or less mTorrs, on the occasion of processing of a sample 40, the directivity of ion increased and perpendicular micro processing became possible. In addition, in 5 or less mTorrs, in order to obtain the same processing speed, while an exhauster and an RF generator are enlarged, dissociation beyond the need of being based on the rise of electron temperature arises, and there is an inclination for a property to deteriorate.
[0159] Generally, the relation between the frequency of the power source for plasma generating using two electrodes of a pair and the minimum gas pressure with which discharge is given to a stabilization target that the stable discharge minimum gas pressure falls is, so that the frequency of a power source becomes high and inter-electrode distance becomes large, as shown in drawing 32 . In order to operate effectively the effectiveness of avoiding bad influences, such as a surrounding wall and a depository to the discharge confinement ring 37, and removing the fluorine and oxygen by the up electrode covering 30, the susceptor covering 39, the resist in a sample, etc., it is desirable to set inter-electrode distance to about 50mm or less corresponding to 25 or less times of the average free process at the time of highest gas pressure 40mTorr. Moreover, as an inter-electrode distance, if it is not more than two to 4 time (4mm - 8mm)

extent of the average free process at the time of the highest gas pressure (40mTorr), stable discharge will become difficult.

[0160] In the example shown in drawing 31 , in order to use 30MHz - 200MHz high-frequency power desirably, even if it makes 20MHz - 500MHz of gas pressure of the processing interior of a room into the low voltage of 0.5-4.0Pa as RF generator 16 for plasma generating, the stable plasma is acquired and micro-processing nature can be raised. Moreover, by using such high-frequency power, dissociation of the gas plasma becomes good and the selection-ratio control at the time of sample processing becomes good.

[0161] In the example of this invention described above, possibility that interference will arise between the output of pulse bias power supply and the output of the power source for plasma generating is also considered. Then, this cure is described hereafter.

[0162] First, pulse-width:T1, a pulse period: In the ideal rectangular pulse which has the standup / falling rate of infinity by T0, as shown in drawing 33 , f<=3f of about 70 - 80% of power is contained in the frequency range of 0 (f0= (1/T1)). Since the wave actually impressed starts and becomes limited [a /falling rate], the convergency of power improves further and f<=3f of about 90% or more of power can be contained in the frequency range of 0.

[0163] 3f0 It is 0 f<=3f to 3f0 which prepares a counterelectrode almost parallel to a sample and can be found in the-three number of degree types in order for pulse bias with a high frequency component to be made to be impressed in a sample side by homogeneity. It is desirable to ground the frequency component of the range.

[0164]

[Equation 3]

$$T_1=0.2\,\mu s とすると\quad 3f_0=3\cdot\frac{10^6}{0.2}=15MHz$$

$$T_1=0.1\,\mu s とすると\quad 3f_0=30MHz \qquad \cdots\cdots 数3$$

[0165] The example shown in drawing 31 is coping with interference with the above-mentioned pulse bias-power-supply output and the power outlet for plasma generating. That is, in this plasma etching system, RF generator 16 for plasma generating is connected to a sample 40 and the up electrode 12 which counters. In order to make the section electrode 12 into the touch-down level of pulse bias besides, it is the frequency f1 of RF generator 16 for plasma generating. Above 3f0 It enlarges and is f=f1. The impedance in the neighborhood is large and the band eliminator 141 with a low impedance is connected between the up electrode 12 and touch-down level on other frequencies.

[0166] On the other hand, it is f=f1. The impedance in the neighborhood is low and other frequencies install the band pass filter 142 with a high impedance between the sample base 15 and touch-down level. If such a configuration is used, interference between the output of the pulse bias power supply 17 and power-source 16 output for plasma generating can be suppressed on satisfactory level, and good bias can be added to a sample 40.

[0167] Drawing 34 is the example which is an inductive-coupling mold discharge method among external energy supply discharge methods, and applied this invention to the non-magnetic field type plasma etching system. It is the RF generator to which 52 impresses a flat-surface coil to a flat-surface coil, and 54 impresses the high-frequency voltage of 10MHz - 250MHz. Compared with the method having shown the inductive-coupling mold discharge method in drawing 10 , it is a low frequency and low voltage and stable plasma generating are attained. On the contrary, since dissociation becomes easy to progress, as drawing 1 showed, the output of RF generator 1 can be modulated by the source 161 of an RF generator modulating signal, and unnecessary dissociation can be prevented. The processing room 10 as a vacuum housing is equipped with the sample base 15 where a sample 40 is laid on the electrostatic adsorption film 22.

[0168] When performing etching processing, the pressure of the processing room 10 is evacuated to 0.5-4.0Pa by carrying out evacuation with an another side vacuum pump, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing raw gas into the processing room 10 by the predetermined flow rate from a gas supply system (not shown). Next, the high-frequency voltage of 13.56MHz is applied to RF generator 54, and the processing room 10 is made to generate the plasma. Etching processing of the sample 40 is carried out using this plasma. On the other hand, at the time of etching, a period impresses the pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds. It is as the amplitude of pulse bias voltage having stated that the range changes with membrane types in the example of drawing 1 . Impression of this pulse bias voltage performs the ion in the plasma, and highly precise configuration

control or selection-ratio control is performed in a sample acceleration and by making it put perpendicular ON. Thereby, even if the resist mask pattern of a sample is very detailed, highly precise etching processing can be performed.
[0169] Moreover, as shown in drawing 35 , in an inductive-coupling mold discharge method non-magnetic field type plasma etching system, the Faraday shield plate 53 which has a clearance in the processing room 10 side of an induction ******** output, and the 0.5mm - 5mm thin electric insulating plate 54 for shielding plate protection may be installed, and the Faraday shield plate may be grounded. While decreasing the capacity component between a coil and the plasma, being able to fall the energy of ion which strikes the quartz plate under the coil 52 in drawing 34 , and the electric insulating plate 54 for shielding plate protection and lessening damage on a quartz plate or an electric insulating plate by installation of the Faraday shield plate 53, mixing of the foreign matter to the inside of the plasma can be prevented.
[0170] Moreover, since the Faraday shield plate 53 serves also as the duty of the earth electrode of the pulse bias power supply 17, it can impress pulse bias to homogeneity between a sample 40 and the Faraday shield plate 53. In this case, the filter installed in an up electrode or the sample base 15 is unnecessary.
[0171] Drawing 36 is the front view which carried out the longitudinal section of some equipments which applied this invention to microwave plasma treatment equipment. The pulse bias power supply 17 and DC power supply 13 are connected to the lower electrode 15 as a sample base 15 where a sample 40 is laid on the electrostatic adsorption film 22. 41 is a magnetron as a source of an oscillation of microwave, 42 is the waveguide of microwave, and 43 is a quartz plate for carrying out the vacuum lock of the processing room 10, and supplying microwave to the processing room 10. The first solenoid coil with which 47 supplies a magnetic field, and 48 are the second solenoid coil which supplies a magnetic field. 49 is a raw gas supply system and supplies the raw gas which processes etching, membrane formation, etc. in the processing room 10. Moreover, evacuation of the processing room 10 is carried out by the vacuum pump (not shown). The property required for the pulse bias power supply 17 and the electrostatic chuck 20 is the same as that of the example of drawing 1 , and is omitted for details.
[0172] When performing etching processing, the pressure of the processing room 10 is evacuated to 0.5-4.0Pa by carrying out evacuation with an another side vacuum pump, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing raw gas into the processing room 10 by the predetermined flow rate from a gas supply system 49. Next, the second solenoid coil 47 and 48 is set to ON, and the processing room 10 is made to generate ******** and the plasma for the microwave generated in the magnetron 41 from a waveguide 42 a magnetron 41 and for a start. Etching processing is performed in a sample 40 using this plasma. On the other hand, at the time of etching, a period impresses the pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds.
[0173] Highly precise configuration control or selection-ratio control is performed by accelerating in a sample and carrying out incidence of the ion in the plasma perpendicularly by impression of such pulse bias voltage. Thereby, even if the resist mask pattern of a sample is very detailed, vertical incidence can perform highly precise etching processing corresponding to a mask pattern.
[0174] In addition, in the plasma etching system of this invention shown below in drawing 1 , the direct current voltage of an electrostatic adsorption circuit and the pulse voltage of a pulse bias-power-supply circuit can be superimposed and generated, and a circuit can also be constituted in common. Moreover, it separates into another electrode, an electrostatic adsorption circuit and a pulse bias-power-supply circuit are prepared, and pulse bias can be prevented from affecting electrostatic adsorption.
[0175] It can replace with the electrostatic adsorption circuit in the example of the plasma etching system shown in drawing 1 , and can also use, other adsorption means, for example, vacuum adsorption means.
[0176] Plasma treatment equipment equipped with the electrostatic adsorption circuit of this invention and pulse bias voltage impression circuit which were described above is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.
[0177] Next, the conventional fault is improved, ion, the amount of radical formation, and quality are controlled by other examples of this invention shown in drawing 37 , and other examples of the plasma etching system which makes very detailed plasma treatment possible are described.
[0178] That is, the location which performs the first plasma production is set as a location different from a vacuum processing room by the upstream of a vacuum processing room which is installing the sample, the metastable atom generated there is poured into a vacuum processing room, and it is considering as the configuration which generates the second plasma at a vacuum processing room. In addition to the plasma etching system shown in drawing 1 , it has the gas supply section 60 for the sources of an ion radical, and

the plasma generating room 62 for metastable atom generating. Moreover, the introductory root connected to the gas supply section for the sources of an ion radical other than the root which introduces the gas containing a metastable atom into a vacuum processing room is established in the up electrode 12.
[0179] The description of this example is as follows.
** High-frequency power is impressed, plasma-ize the gas supplied from the gas supply section 36 for metastable atom generating at the plasma generating room 62 for metastable atom generating, carry out the amount generating of requests of the desired metastable atom beforehand, and make it flow into the processing room 10. The plasma generating room 62 for metastable atom generating sets an indoor pressure as the high pressure of hundreds mTorr(s) - dozens Torr(s) in order to generate a metastable atom efficiently.
[0180] ** Make the gas from the gas supply section 60 for another side and the sources of an ion radical flow into the processing room 10.
[0181] ** Output the RF of comparatively the low power in the power source 16 for plasma generating, and make the processing room 10 generate the plasma. By impregnation of a metastable atom, since the electron of low energy about 5eV or less can also make ion generate efficiently, it is low electron temperature (about 6eV or less, preferably about 4eV or less), and little [sharply] plasma is acquired for a high energy electron about 15eV or more. For this reason, the gas for the sources of a radical can secure a complement and quality, without producing superfluous dissociation. On the other hand, the amount of ion is controllable by the amount of the metastable atom generated at the plasma generating room 62 for metastable atom generating, and the gas for the ion sources from the gas supply section 60 for the sources of an ion radical.
[0182] Thus, since the quality and the amount of ion and radical formation can be controlled, the good engine performance is obtained also in very detailed plasma treatment. The gas (C2H4, CH4, CH3OH, etc.) which contains C and H in fluorocarbon gas, such as CHF3, CH2F2, C4F8, or CF4, as gas for the sources of a radical if needed is mixed, and it is. As gas for metastable atom generating, what made **-SU one kind or two kinds of rare gas is used. Ion is efficiently generable by using rare gas with the following property etc. as gas for the ion sources.
[0183] At least energy ** of said metastable atom is received, and although the direction like ****** of the thing which has at least low ****** of the gas for the ion sources, or the gas for the ion sources is high, a thing with the small (about 5eV or less) difference is used.
[0184] In addition, although it falls efficiently, it cannot add especially as gas for the ion sources, but the above-mentioned gas for metastable atom generating and the gas for the sources of a radical can also be substituted.
[0185] Next, other examples of this invention which controls the quality and the amount of ion and radical formation to drawing 38 are shown. Although the fundamental idea is the same as drawing 37 , in drawing 37 , its distance between the plasma room 62 for metastable atom generating and the vacuum processing room 10 is long, and it is an example carried out as a cure when attenuation of a metastable atom during this period is large. 41 is a magnetron as a source of an oscillation of microwave, 42 is the waveguide of microwave, it is a quartz plate for 43 carrying out vacuum **** of the first plasma production room 45, and passing microwave, and 44 is a quartz plate for gas distribution. At the first plasma production room 45, the plasma is generated by said microwave in the gas pressure of several 100 mTorr(s) to several 10 Torr(s), and a metastable atom is generated.
[0186] In drawing 38 , since the source location of a metastable atom and distance between vacuum processing rooms can be shortened as compared with drawing 37 , a metastable atom can be poured into a vacuum processing room by the high consistency, and the amount of the ion in the vacuum processing room 10 can be increased. The processing room 10 is maintained at the pressure of 5 - 50mTorr, and by RF generator 16 20MHz or more, 5eV of high density low electron-temperature plasma of 3 is preferably generated cm 11th power a set /from the 10th power of 10 in 3eV or less, and ionization of the gas for the ion sources is advanced, avoiding dissociation of CF2 which needs 8eV or more as dissociation energy. Consequently, on the front face of a sample 40, the following reaction assisted by the incidence of the ion accelerated by several 100 V by bias power supply 17 mainly advances.
SiO2+2CF2 -> In CF2, since Si or SiN used as furring which are SiF4 **+2CO ** were not etched, oxide film etching of a high selection ratio of them was attained.
[0187] Moreover, the increment of F according a part to dissociation in CF2 is decreased with the up electrode covering 30 which consists of silicon, carbon, or SiC.
[0188] As stated in the top, by adjusting the gas for the sources of a radical, and the gas for the ion sources, the ratio of the ion in the processing room 10 and a radical could be controlled almost

independently, and it became easy to control the reaction in the front face of a sample 40 to a desired thing.
[0189] Plasma treatment equipment equipped with the electrostatic adsorption circuit and pulse bias voltage impression circuit of this invention is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.
[0190] Next, other examples of this invention which controls ion and a radical independently to drawing 39 are shown. In drawing 39 , the gas (C2H4, CH3OH, etc.) which contains C and H in fluorocarbon gas, such as CHF3, CH2F2, C4F8, or CF4, if needed is mixed, and it puts into the plasma generating room 62 for radical generating via a bulb 70 from the part which drawing 39 A Becomes.
[0191] At the plasma generating room 62 for radical generating, the output of the RF power source (several MHz or several 10MHz) 63 is impressed to a coil 65, the plasma is generated with the gas pressure of several 100 mTorr(s) to several 10 Torr(s), and CF2 radical is mainly generated. CF3 and F which are generated in coincidence are decreased by H component.
[0192] In addition, since it is difficult to decrease components, such as CF and O, sharply at the plasma generating room 62 for radical generating, the unnecessary component removal room 65 is formed next. Here, the wall of the quality of the materials (carbon, Si, SiC, etc.) containing carbon or Si is installed, and an unnecessary component is transformed to reduction or another gas with few bad influences. The outlet of the unnecessary component removal room 65 is connected to a bulb 71, and CF2 supplies the gas presentation of a principal component.
[0193] In addition, since deposits, such as a depository object, are accumulated between [many] a bulb 70 and a bulb 71, they need cleaning and exchange for a short period of time comparatively. For this reason, while making atmospheric-air disconnection and exchange easy, it has connected with an exhauster 74 via a bulb 72 for compaction of the vacuum starting time amount at the time of re-starting. In addition, an exhauster 74 may be used also [exhauster / for the processing rooms 10].
[0194] Moreover, the gas B for the ion sources (rare gas, such as argon gas and xenon gas) is supplied to the aforementioned outlet and aforementioned connector processing room of a bulb 71 via a bulb 73.
[0195] The processing room 10 is maintained at the pressure of 5-40mT, and by RF generator 16 20MHz or more which became irregular, 5eV of high density low electron-temperature plasma of 3 is preferably generated cm 11th power a set /from the 10th power of 10 in 3eV or less, and ionization of the gas for the ion sources is advanced, avoiding dissociation of CF2 which needs 8eV or more as dissociation energy. Consequently, on the front face of a sample 40, the following reaction assisted by the incidence of the ion accelerated by several 100 V by bias power supply 17 mainly advances.
SiO2+2CF2 -> In CF2, since Si or SiN used as furring which are SiF4 ***+2CO ** were not etched, oxide film etching of a high selection ratio of them was attained.
[0196] Moreover, the increment of F according a part to dissociation in CF2 is decreased with the up electrode covering 30 which consists of silicon, carbon, or SiC.
[0197] As stated in the top, by adjusting the gas A for the sources of a radical, and the gas B for the ion sources, the ratio of the ion in the processing room 10 and a radical could be controlled almost independently, and it became easy to control the reaction in the front face of a sample 40 to a desired thing. Moreover, since an unnecessary depository component etc. was eliminated at the unnecessary component removal room 65 and he was trying not to carry into the processing room 10 as much as possible, the depository in the processing room 10 was reduced sharply, and the frequency of cleaning where opened the processing room 10 wide to atmospheric air, and it was performed has also reduced it sharply.
[0198] Next, other examples which control ion and a radical independently to drawing 40 are shown. From A, it mixes with ion source gas B via through, the unnecessary component removal room 65, and a bulb 71 in the heating pipe section 66 via a bulb 70, and oxidation hexafluoropropylene gas (it omits CF3CFOCF2 and Following HFPO) is sent to the way of the processing room 10. In the heating pipe section 66, HFPO is heated at 800 degrees C - 1000 degrees C, and the following pyrolysis generates CF2.
CF3CFOCF2 -> Although the comparatively stable matter is hard to decompose CF2+CF3CFOCF3CFO, since a part is understood and unnecessary O and F are generated, the unnecessary component removal room 65 was formed after the heating pipe section 66, and the unnecessary component has been changed into the matter out of which removal or a bad influence does not come. A part of CF3CFOCF(s)2 flow into the processing room 10 without decomposing, but with the plasma 5eV or less of low electron temperature, in order not to dissociate, they do not pose a problem.
[0199] In addition, the reaction in how to use a bulb 72 and an exhauster 74 and the processing room 10 is

the same as the case of drawing 39 .

[0200] Plasma treatment equipment equipped with the electrostatic adsorption circuit and pulse bias voltage impression circuit of this invention is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.

[0201]

[Effect of the Invention] According to this invention, precise processing of a detailed pattern is easy about the sample of the diameter of macrostomia beyond phi300mm, and the plasma treatment equipment and the plasma treatment approach which the selection ratio at the time of micro processing also raised can be offered. Moreover, the plasma treatment equipment which can perform homogeneity and high-speed processing, especially oxide-film processing over the whole surface of the sample of the diameter of macrostomia, and its art can be offered.

[0202] According to this invention, the plasma treatment equipment and the plasma treatment approach which raised the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be offered further.

[0203] Moreover, a controllability can acquire good and narrow ion energy distribution, and can offer the plasma treatment equipment and the plasma treatment approach which raised the selectivity of plasma treatment etc.

[0204] Moreover, when using the sample base which has a dielectric layer for electrostatic adsorption, a controllability is good, narrow ion energy distribution can be acquired and the plasma treatment equipment and the plasma treatment approach which raised the selectivity of plasma treatment etc. can be offered.

[0205] Moreover, by controlling the amount and the quality of ion and a radical independently, the pressure of the processing interior of a room of plasma treatment equipment is made low, and precise processing of a detailed pattern is easy, and can offer the plasma treatment equipment and the plasma treatment approach which the selection ratio at the time of micro processing also raised.

[0206] The plasma treatment equipment and the plasma treatment approach which raised the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be offered by controlling the amount and the quality of ion and a radical independently further again.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to suitable plasma treatment equipment to start plasma treatment equipment and an art, especially form the detailed pattern in a semi-conductor production process, and the plasma treatment approach.

[Translation done.]

PRIOR ART

[Description of the Prior Art] As for plasma treatment, improvement in micro-processing nature or processing speed has been increasingly required with high integration of a semiconductor device. In order to meet this demand, low-voltage-izing of processing gas pressure and the densification of the plasma are needed.
[0003] There are some (it abbreviates to ICP) which a coil is excited [some] according to the power source of the thing using the cyclotron-resonance phenomenon (it abbreviates to ECR) of (1) microwave (2.45GHz) electromagnetic field and a static magnetic field (875G) and (2) RF frequency as what aims at low-voltage-izing of processing gas pressure and densification, generate induction field, and generate the plasma.
[0004] By the way, when etching the film of an oxide film system using fluorocarbon system gas, the present condition is that it is difficult for dissociation of gas to progress too much and to make high the selection ratio to the substrate (Si and SiN) of the oxide film system film by the ICP method shown in ECR shown above (1) or (2).
[0005] The conventional method of impressing the electrical potential difference of RF frequency between parallel plates, and on the other hand, generating the plasma is difficult for making stability discharge by the pressure of 10Pa or less. As [showed / in (3) JP,7-297175,A or JP,3-204925,A / as this cure] The 2 cycle exciting method for making an electrical potential difference with a high frequency of dozens of MHz or more generate the plasma, and performing bias control of a sample on the low frequency of several MHz or less, (4) -- the magnetron RIE (it abbreviates to M-RIE) which Field B was added in the direction which intersects the auto-bias electric field (E) by which induction was carried out to the sample front face as shown in JP,2-312231,A, and the electron by the electronic Lorentz force shut up, and used the operation -- there is law.
[0006] Moreover, there are some which were indicated by JP,56-13480,A as an approach of making a plasma consistency increasing to the bottom of low gas pressure. This utilizes the electron cyclotron resonance (ECR) by the microwave (2.45GHz) and static magnetic field (875Gauss) which are an electromagnetic wave, and a plasma consistency even with the high low gas pressure of 0.1-1Pa is obtained.
[0007] The processor equipped with the RF generator for accelerating the ion in the plasma and the electrostatic adsorption film which makes a sample hold on a sample base by electrostatic adsorption power on the other hand to the sample base which arranges a processed material (for example, it abbreviates to a semi-conductor wafer substrate and a following sample.) in the technical field which performs etching processing, membrane formation processing, etc. of a semi-conductor using the plasma is adopted.
[0008] For example, the equipment indicated by the USP No. 5,320,982 specification controls the ion energy which connects this power source to a sample base by using the RF generator of a sinusoidal output as bias power supply, and carries out incidence to a sample, making heat transfer gas intervene between a sample and a sample base, and performing temperature control of a sample, while generating the plasma with microwave and making a sample hold on a sample base by electrostatic adsorption power.
[0009] Moreover, it is indicated that it becomes possible to be able to narrow distribution width of face of the ion energy which carries out incidence to a sample by generating the ion control bias wave of the shape of a pulse which fixed-izes plasma inter-electrode field strength, and being impressed by the sample base, and to raise the processing dimensional accuracy of etching and the etching velocity ratio of the processed film and substrate material several times in JP,62-280378,A.
[0010] Moreover, it is indicated by JP,6-61182,A that generate the plasma using a electron cyclotron

resonance, and pulse duty impresses the pulse bias of about 0.1% or more of width of face, and prevents generating of a notch in a sample.
[0011] In addition, the thing of a publication is in Jap.J.Appl.phys, Vol.28, No.10, October, 1989, and PP.L 1860-L 1862 as an example as for which cyclotron resonance raises a lifting and a plasma consistency by the VHF electrification magnetic wave and the static magnetic field. However, a 144MHz RF is impressed to the central conductor of a coaxial configuration by this example, the magnetic field of 51G parallel to a central conductor is added, cyclotron resonance is produced, PURAZU of high density is generated, and the sample base grounded to the lower stream of a river of this plasma generating section is installed.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, precise processing of a detailed pattern is easy about the sample of the diameter of macrostomia beyond phi300mm, and the plasma treatment equipment and the plasma treatment approach which the selection ratio at the time of micro processing also raised can be offered. Moreover, the plasma treatment equipment which can perform homogeneity and high-speed processing, especially oxide-film processing over the whole surface of the sample of the diameter of macrostomia, and its art can be offered.
[0202] According to this invention, the plasma treatment equipment and the plasma treatment approach which raised the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be offered further.
[0203] Moreover, a controllability can acquire good and narrow ion energy distribution, and can offer the plasma treatment equipment and the plasma treatment approach which raised the selectivity of plasma treatment etc.
[0204] Moreover, when using the sample base which has a dielectric layer for electrostatic adsorption, a controllability is good, narrow ion energy distribution can be acquired and the plasma treatment equipment and the plasma treatment approach which raised the selectivity of plasma treatment etc. can be offered.
[0205] Moreover, by controlling the amount and the quality of ion and a radical independently, the pressure of the processing interior of a room of plasma treatment equipment is made low, and precise processing of a detailed pattern is easy, and can offer the plasma treatment equipment and the plasma treatment approach which the selection ratio at the time of micro processing also raised.
[0206] The plasma treatment equipment and the plasma treatment approach which raised the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be offered by controlling the amount and the quality of ion and a radical independently further again.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] A plasma generating method given in JP,7-288195,A or JP,7-297175,A generates the plasma by the RF (13.56MHz and dozens of MHz) among the above-mentioned conventional technique. Etching of an oxide film can be made to generate the good plasma in the gas pressure of dozens-5Pa (pascal) extent. However, with detailed-izing with a pattern dimension of about 0.2 micrometers or less, perpendicular-ization of a processing configuration is required more strongly and, for that, the fall of gas pressure is becoming indispensable.
[0013] However, it is difficult to make stability generate the plasma of the consistency of the request of 5x1010cm ~ 3 or more about by 4Pa or less (0.4-4Pa) by the above-mentioned 2 cycle exciting method and the above-mentioned M-RIE method. For example, even if it makes the plasma excitation frequency high by the above-mentioned 2 cycle exciting method, it is difficult for reduction which a plasma consistency seldom increases above about 50MHz, or falls conversely to come out, and to make a plasma consistency or more [5x1010cm ~] into three with the low gas pressure of 0.4-4Pa.
[0014] Moreover, the plasma consistency which the electron by the Lorentz force of the electron produced on a sample front face shuts up by the M-RIE method, and is generated by operation must be uniform all over a sample. However, generally a plasma consistency has the fault which the deviation within a field produces by the drift of ExB. Since it generates near the sheath near [where field strength is strong] the sample, the deviation of the plasma consistency which an electron shuts up in a sample front face directly, and is formed in an operation cannot be amended by approaches, such as diffusion.
[0015] uniform PURAZUMAGA profit **** which do not have a bias even if it adds 200 gauss as maximum of a magnetic field parallel to a sample by arranging a magnet so that magnetic field strength may become weak in the direction of a drift of the electron by ExB as indicated by JP,7-288195,A as this solution. However, since it will be limited to the specific narrow range with the conditions from which the plasma becomes uniform once it fixes magnetic-field-strength distribution, change of processing conditions has the fault which cannot follow in footsteps easily. Especially, in order for the pressure on a sample center section to become high ten percent or more from the pressure on a sample edge when narrow, and to avoid the differential pressure on a sample, when an inter-electrode distance is about 20mm or less to the diameter sample of macrostomia beyond phi300, and setting spacing between a sample base and a counterelectrode as 30mm or more, it is in the inclination especially whose difficulty increases.
[0016] Thus, by the above-mentioned 2 cycle exciting method and the above-mentioned M-RIE method, it is the low voltage of 0.4 to 4 Pa, and it is difficult to make the plasma consistency of 5x1010cm~3 into homogeneity in a phi300mm sample side. Therefore, by the 2 cycle exciting method or the M-RIE method, it is in a difficult situation for it to be uniform, and to have high-speed workability to the wafer of the diameter of macrostomia beyond phi300mm, and to process a selection ratio with substrates (Si, SiN, etc.) for processing below the diameter of 0.2 micron highly.
[0017] On the other hand, there are some which were indicated by JP,56-13480,A in the above-mentioned conventional technique as an approach to which the plasma consistency by low gas pressure is made to increase sharply. However, by this method, dissociation of gas progressed too much, and when silicon oxide, a nitride, etc. were etched using the gas containing a fluorine and carbon, a fluorine atom / molecule, and fluorine ion were generated so much, and there was a fault that a selection ratio with desired substrates (Si etc.) was not obtained. The ICP method using the induction field of RF power also had the fault to which dissociation progresses too much like the describing [above] ECR method.
[0018] Moreover, generally the configuration which exhausts raw gas from the circumference of a sample is taken, in this case, the consistency of a sample center section was high, it became the inclination for the plasma consistency of a sample periphery to become low, and there was a fault by which the homogeneity

of processing on the whole sample surface is spoiled. Although preparing an annular bank (focal ring) near the circumference of a sample, and stagnating a gas stream was performed in order to improve this fault, it had the fault to which a resultant adheres, it becomes a foreign matter generation source, and the yield falls to this bank.

[0019] On the other hand, in order that the ion which carries out incidence to a sample may carry out energy control, adding RF bias of a sine wave to the electrode which lays a sample is performed. Although several 100kHz - 13.56MHz was used as that frequency, since ion followed in footsteps of change of the electric field in a sheath, with this frequency band, the energy distribution of the ion which carries out incidence had become the double peak mold which has a peak by two by the side of low energy and high energy. Although the processing speed of the ion by the side of high energy was high, the damage was given to the sample, and when there is a fault with low processing speed and it was going to lose the damage, processing speed fell, and the ion by the side of low energy had the fault from which a damage poses a problem, when it was going to gather processing speed. On the other hand, although the energy distribution which carries out incidence approached the single peak together, the greater part of the energy was used for plasma production, and when RF bias frequency was made into the high value of about 50MHz or more, since the electrical potential difference which joins a sheath fell sharply, there was a fault to which it becomes difficult to control the energy of incidence ion independently.

[0020] Moreover, a pulse bias-power-supply method given in JP,62-280378,A or JP,6-61182,A among the above-mentioned conventional technique The examination in the case of impressing pulse bias to a sample between a sample base electrode and a sample using the dielectric layer for electrostatic adsorption is not made. Since the ion acceleration voltage impressed between the plasma and a sample front face by the increment in the electrical potential difference generated among the both ends of an electrostatic adsorption film with the inflow of the ion current will fall and ion energy distribution will spread, if it applies to an electrostatic adsorption method as it is, There was a fault which cannot cope with processing of the detailed pattern to need performing sufficient temperature control for a sample.

[0021] moreover , by the conventional sinusoidal output bias power supply method indicated by the USP No. 5,320,982 specification , if a frequency became high , since the impedance of the sheath section would approach the own impedance of plasma or would become less than [it] , the unnecessary plasma arose near the sheath near the sample by bias power supply , while no longer be use effective in an acceleration of an ion , plasma distribution also got worse , and there be a fault in which the controllability of the ion energy by bias power supply be lose .

[0022] The limit of the control is becoming clear as processing of a sample makes it detailed in plasma treatment further again, since the gas by which it serves as the ion source and a source of a radical conventionally although it is important to control the amount of ion, the amount of radicals, and a radical kind proper because of the improvement in the engine performance was made to flow into a processing room, the plasma was generated in the processing interior of a room and coincidence was made to generate ion and a radical.

[0023] Moreover, the means for applying to homogeneity the installation bias voltage of the bias power supply impressed to a sample base over the whole sample side surface etc. is not described by the example using the cyclotron resonance of Jap.J.Appl.phys described previously and VHF ** of 28 and 10. Moreover, it is difficult for the height of a processing room to be about 200mm or more, and for the configuration utilized for the surface reaction owner effect in a counterelectrode not to become, but to obtain a high selection ratio with this configuration.

[0024] The purpose of this invention has precise processing of the detailed pattern to the sample of the diameter of macrostomia in offering easy plasma treatment equipment and the plasma treatment approach by not advancing dissociation of gas too much but acquiring the uniform plasma with the diameter of macrostomia beyond phi300mm.

[0025] Other purposes of this invention are to offer the plasma treatment equipment which can perform homogeneity and high-speed processing, especially oxide-film processing over the whole surface of the sample of the diameter of macrostomia, and its art.

[0026] Other purposes of this invention are to offer the plasma treatment equipment and the plasma treatment approach which raised the selection ratio of plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.).

[0027] Other purposes of this invention are to offer the plasma treatment equipment and the plasma treatment approach which acquire narrow ion energy distribution, are stabilized and can improve the selection ratio of plasma treatment with a sufficient controllability by the low damage.

[0028] Other purposes of this invention are to offer the plasma treatment equipment and the plasma

treatment approach of improving temperature control nature by electrostatic adsorption of a sample, being stabilized with a sufficient precision and performing processing of the detailed pattern to need.
[0029] Other purposes of this invention are to offer the plasma treatment equipment which can control ion and a radical independently, and the plasma treatment approach.

[Translation done.]

MEANS

[Means for Solving the Problem] In the plasma treatment equipment with which the description of this invention has a vacuum processing room, the plasma production means containing the electrode of a pair, the sample base that has the sample installation side in which the sample by which it is processed in this vacuum processing interior of a room is laid, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the high-frequency power of VHF ** (30MHz thru/or 300MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator It has the magnetic field means forming which forms a static magnetic field or a low frequency magnetic field, and is in forming the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[0031] A plasma production means by which other descriptions of this invention contain a vacuum processing room and the electrode of a pair, In the plasma treatment equipment which has the sample base in which the sample processed in this vacuum processing interior of a room is laid while serving as one side of said electrode, and a reduced pressure means to decompress said vacuum processing room The RF generator which impresses the VHF electrification force (50MHz thru/or 200MHz) to inter-electrode [of said pair], In the direction which intersects the electric field produced inter-electrode [of said pair], or near it by said RF generator It has the magnetic field means forming which forms the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency magnetic field. The part used as the max of the component of a direction along the field of said sample base of said magnetic field sets up so that it may become said sample base and opposite side from the center of the electrode of said pair, and it is to form the cyclotron-resonance field of the electron by the interaction of said magnetic field and said electric field in inter-electrode [of said pair].
[0032] A plasma production means by which other descriptions of this invention contain a vacuum processing room and the electrode of a pair, In the plasma treatment approach of the sample by the plasma treatment equipment which has a sample base for arranging the sample processed in this vacuum processing interior of a room while serving as one side of said electrode, and a reduced pressure means to decompress said vacuum processing room By the step which decompresses said vacuum processing interior of a room with a reduced pressure means, and magnetic field means forming The step which forms the part of a static magnetic field 10 gauss or more 110 gauss or less or a low frequency magnetic field in the direction which intersects the inter-electrode electric field of said pair, The VHF electrification force (30MHz thru/or 300MHz) is impressed to inter-electrode [of said pair] by the RF generator. Between the electrodes of said pair It is in having the step which forms the cyclotron-resonance field of the electron by the interaction with the electric field by said magnetic field and said RF generator, and the step which processes said sample by the plasma by which ** Li generation is carried out at the cyclotron resonance of said electron.
[0033] In order that according to this invention dissociation of gas may not be advanced too much but saturation ion current distribution may acquire **5% or less of uniform plasma with the diameter of macrostomia beyond phi300mm, as an RF generator for plasma production, 30MHz cannot be found and 300MHz (50MHz thru/or 200MHz) of VHF is used preferably. A static magnetic field or a low frequency magnetic field is formed in the direction which, on the other hand, intersects the electric field produced in inter-electrode [of a pair] by said RF generator. Thereby, with a sample base, the cyclotron-resonance field of the electron by the interaction of a magnetic field and electric field is formed in the opposite side rather than the center of the electrode of this pair along the sample installation side of a sample base inter-electrode [of a pair]. A sample is processed to the cyclotron resonance of this electron by the

plasma by which ** Li generation is carried out.
[0034] A magnetic field has the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency (1kHz or less) magnetic field preferably 10 gauss or more 110 gauss or less, and gas is made into the low voltage of 0.4Pa thru/or 4Pa. Moreover, there is no 30 and distance between two electrodes is preferably set to 30 thru/or 60mm 100mm. In addition, it cannot be overemphasized that the electrode of a pair is what has the area more than the area of the sample processed, respectively.
[0035] As a frequency f of an RF generator, by using 50 MHz<=f<=200MHz VHF, a plasma consistency does not have a single figure compared with the case of microwave ECR, and falls about double figures. Moreover, dissociation of gas also falls and unnecessary fluorine atom / molecule, and generating of ion also fall about single or more figures. Three or more [5x1010cm ~] processings of low-pressure and a high rate which the plasma with a high consistency is acquired moderately and are 0.4 to 4 Pa are attained as an absolute value of a plasma consistency the frequency of this VHF band, and by using cyclotron resonance. Furthermore, in order that dissociation of gas may not progress too much, either, a selection ratio with substrates, such as Si and SiN, is not worsened greatly.
[0036] Although dissociation of gas will progress for a while if compared with the 13.56MHz conventional parallel plate electrode, the fluorine atom / molecule by this, and the slight increment in ion can improve by installing the matter which contains silicon and carbon in an electrode surface or a chamber wall surface, or combining and discharging hydrogen and a fluorine further using adding bias to these, and the gas containing hydrogen.
[0037] Moreover, according to this invention, the part which serves as max of a magnetic field component parallel to a sample base between two electrodes is set as a sample base and the opposite side rather than the center of two electrodes. By making preferably magnetic field strength parallel to the sample in respect of sample installation of a sample base into 15 gauss or less 30 gauss or less The Lorentz force (ExB) committed into an electron near a sample installation side can be made into a small value, and generating of the heterogeneity of the plasma consistency by the electronic drift condenser by the Lorentz force in respect of sample installation can be abolished.
[0038] According to other descriptions of this invention, compared with near the center section of the sample, the electronic cyclotron-resonance effectiveness is enlarged on a periphery or its outside compared with a center so that generation of the plasma may be raised a periphery or near [its] an outside a sample. It can attain by making distance of a cyclotron-resonance field and a sample far, losing a cyclotron-resonance field, or lessening the rectangular degree of a magnetic field and electric field as a means which lowers the electronic cyclotron-resonance effectiveness, etc.
[0039] Moreover, if the field gradient near cyclotron-resonance magnetic field BC is made sudden and an ECR resonance region is narrowed, the cyclotron-resonance effectiveness can be weakened. An ECR resonance region is Bc(1-a) <=B<=Bc (1+a). However, it becomes the range of the magnetic field strength B which becomes 0.05 <=a<=0.1.
[0040] In an ECR resonance region, in order that dissociation may progress, especially generation of ion prospers. On the other hand, dissociation does not progress compared with an ECR resonance region, but, as for fields other than an ECR resonance region, the direction of generation of a radical prospers. By adjusting the high-frequency power applied to the width of face and the up electrode of an ECR resonance region, generating of the suitable ion for processing of a sample and a radical can be controlled more nearly independently.
[0041] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, While having a pulse bias impression means to impress pulse bias voltage to said sample and impressing the high-frequency voltage of 10MHz - 500MHz as said RF generator, it is in having constituted so that said vacuum processing room might be decompressed to 0.5-4.0Pa.
[0042] A sample base for other descriptions of this invention to arrange the sample processed at a vacuum processing room and this vacuum processing room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, It connects with said sample base and is in having established a pulse bias impression means to impress pulse bias voltage to this sample base, and an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of said pulse bias voltage corresponding to the electrostatic adsorption capacity of said electrostatic adsorption means.

[0043] The step which arranges a sample to one side of the electrode of the pair which counters with which other descriptions of this invention were prepared in the vacuum processing room, The step which holds this sample to said electrode by electrostatic adsorption power, and the step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which evacuates said ambient atmosphere to 0.5-4.0Pa, and the step which impresses the high-frequency voltage of 10MHz - 500MHz, and plasma-izes etching gas under said pressure, It is in the plasma treatment approach which consists of a step which etches said sample by this plasma, and a step which impresses pulse bias voltage to one [said] electrode.
[0044] The step which arranges a sample to one electrode of the electrode with which other descriptions of this invention counter, The step which holds the arranged this sample to said electrode by electrostatic adsorption power, The step which introduces etching gas into the ambient atmosphere by which said sample has been arranged, The step which plasma-izes the introduced this etching gas, and the step which etches said sample by this plasma, It is in consisting of a step which impresses the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 at the time of this etching, and carrying out plasma treatment of the insulator layers in said sample (for example, SiO2, SiN, BPSG, etc.) to one [said] electrode at it.
[0045] According to other descriptions of this invention, by impressing the pulse-like bias power of a predetermined property to the sample base equipped with an electrostatic adsorption means to have a dielectric layer for electrostatic adsorption, temperature control nature of a sample is fully performed, it is stabilized and processing of the detailed pattern to need can be performed. That is, it has an electrostatic adsorption means to hold a sample on a sample base by electrostatic adsorption power, and a pulse bias impression means to connect with a sample base and to impress pulse bias voltage to this sample base, and duty of the forward direction pulse part adds 1/2 or less pulse bias to a sample through a capacitative element in a period in 0.2 - 2 microseconds.
[0046] Moreover, according to other descriptions of this invention, as an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of pulse bias voltage corresponding to the electrostatic adsorption capacity of an electrostatic adsorption means, electrical-potential-difference change which joins the both ends of a dielectric layer by electrostatic adsorption during a pulse round term constitutes so that it may become 1/2 or less [of the magnitude of pulse bias voltage]. Specifically make thin thickness of the electrostatic chuck film of the dielectric prepared in the front face of a lower electrode, or let a dielectric be an ingredient with large specific inductive capacity. Or the approach of controlling the rise of the electrical potential difference which shortens the period of pulse bias voltage and joins the both ends of a dielectric layer again may be adopted.
[0047] According to other descriptions of this invention, the selectivity of the plasma treatment to the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be raised by impressing the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 to one [said] electrode further again at the time of etching of a sample.
[0048] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A bias impression means to impress bias voltage to said sample, and a radical supply means to have a means to decompose the gas for radical generating beforehand in said vacuum processing room, and to supply the radical of the amount of requests to it, It is in providing a means to supply the gas for ion generating to said vacuum processing room, and a plasma production means to make said vacuum processing room generate the plasma, and using SiO2 as said sample.
[0049] A sample base for other descriptions of this invention to arrange a vacuum processing room and the sample processed in this vacuum processing interior of a room, An electrostatic adsorption means to have a plasma production means containing an RF generator and to be plasma treatment equipment and to hold said sample on said sample base by electrostatic adsorption power, A pulse bias impression means to impress pulse bias voltage to said sample, A plasma supply means for radical generating to plasma-ize the gas for radical generating in said vacuum processing room beforehand, and to supply the radical of the amount of requests to it, While having said plasma production means to supply the gas for ion generating to said vacuum processing room, and to generate the plasma and impressing the high-frequency voltage of 10MHz - 500MHz to said RF generator, it is in being constituted so that said vacuum processing room may be decompressed to 0.5-4.0Pa.
[0050] According to other descriptions of this invention, by controlling the amount and the quality of ion

and RAJIRARU independently and impressing the pulse-like bias power of a predetermined property to the sample base equipped with an electrostatic adsorption means to have a dielectric layer for electrostatic adsorption, temperature control nature of a sample is fully performed, it is stabilized and processing of the detailed pattern to need can be performed.

[0051] Furthermore, the amount and the quality of ion and RAJIRARU are controlled independently, narrow ion energy distribution is acquired, it can be stabilized and the selectivity of plasma treatment etc. can be raised with a sufficient controllability.

[0052] Moreover, the amount and the quality of ion and RAJIRARU are controlled independently, and as an electrical-potential-difference control means to control change of the electrical potential difference generated with impression of pulse bias voltage corresponding to the electrostatic adsorption capacity of an electrostatic adsorption means, electrical-potential-difference change which joins the both ends of a dielectric layer by electrostatic adsorption during a pulse round term constitutes so that it may become 1/2 or less [of the magnitude of pulse bias voltage]. Specifically make thin thickness of the electrostatic chuck film of the dielectric prepared in the front face of a lower electrode, or let a dielectric be an ingredient with large specific inductive capacity. Or the approach of controlling the rise of the electrical potential difference which shortens the period of pulse bias voltage and joins the both ends of a dielectric layer again may be adopted.

[0053] Moreover, according to other descriptions of this invention, the selectivity of plasma treatment with the substrate over the insulator layers in a sample (for example, SiO2, SiN, BPSG, etc.) etc. can be raised by controlling the amount and the quality of ion and RAJIRARU independently and impressing the pulse bias voltage which has the pulse amplitude of 250V-1000V, and the duty ratio of 0.05-0.4 in one [said] electrode at the time of etching of a sample.

[0054] Furthermore, according to other descriptions of this invention, the amount and the quality of ion and RAJIRARU are controlled independently and gas pressure of the processing interior of a room is made into the low voltage of 0.5-4.0Pa, using the high-frequency voltage of 10MHz - 500MHz as an RF generator for plasma generating. Thereby, the stable plasma is acquired. Moreover, by using such high-frequency voltage, ionization of the gas plasma becomes good and the selection-ratio control at the time of sample processing becomes good.

[0055]

[Embodiment of the Invention] The example of this invention is explained below. The first example which applied this invention to the plasma etching system of a counterelectrode mold at drawing 1 is shown first. In drawing 1 , the processing room 10 as a vacuum housing is equipped with the electrode with which the pair which consists of the up electrode 12 and the lower electrode 15 counters. A sample 40 is laid in the lower electrode 15. In order to **** the differential pressure on the sample side when processing the sample of the diameter of macrostomia beyond phi300mm to ten or less percent, as for the gap of two electrodes 12 and 15, it is desirable to be referred to as 30mm or more. Moreover, in order to reduce a fluorine atom, a molecule, and ion, it is desirable to set preferably the reaction on the upper part / lower electrode surface to 60mm or less 100mm or less from a viewpoint utilized effectively. RF generator 16 which supplies radio-frequency energy through a matching box 162 is connected to the up electrode 12. 161 is a source of an RF generator modulating signal. Between the up electrode 12 and the ground, the filter 165 which serves as low impedance to the frequency component of bias power supply 17, and serves as a high impedance to the frequency component of RF generator 16 is connected.

[0056] Surface area of the up electrode 12 installed almost in parallel with a sample base is made larger than the area of the sample 40 processed, and it is constituted so that an electrical potential difference may join homogeneity efficiently in the sheath on a sample side by impression of bias power supply 17.

[0057] The up electrode covering 30 as a removal plate of the fluorine which consists of silicon, carbon, or SiC is formed in the bottom front face of the up electrode 12. Moreover, the gas induction room 34 equipped with the gaseous diffusion plate 32 which diffuses gas in desired distribution is established in the upper part of the up electrode 12. Gas required for processing of etching of a sample etc. is supplied to the processing room 10 through the hole 38 prepared in the gaseous diffusion plate 32, the up electrode 12, and the up electrode covering 30 of the gas induction room 34 from the gas supply section 36. Evacuation of the outside room 11 is carried out by the vacuum pump 18 connected to the outside room through the bulb 14, and the processing room 10 is adjusted to the processing pressure force of a sample. 13 is an insulator. While raising a plasma consistency, in order to attain homogenization of the reaction in a processing room, the ring 37 for [discharge ******] is formed in the perimeter of the processing room 10. Between ** for exhaust air is established in the ring 37 for [discharge ******].

[0058] On the up electrode 12, it intersects perpendicularly with the electric field E formed in inter-

electrode, and the magnetic field means forming 200 for forming a magnetic field parallel to the field of a sample 40 is established. the magnetic field means forming 200 -- a core 201 and electromagnetism -- the coil 202 and the insulator 203 are provided. As a component of the up electrode 12, there is a nonmagnetic material conductor, for example, aluminum and an aluminium alloy. As a component of the processing room 10, there are nonmagnetic material, for example, aluminum and an aluminium alloy, an alumina, a quartz, SiC, etc. The core 201 has the axial symmetry-of-revolution structure of a cross-section abbreviation easy mold of having the core sections 201A and 201B that the field B to which magnetic flux is extended from the central upper part of the processing room 10 to abbreviation parallel along with the up electrode 12 toward the up electrode 12 at a periphery should be formed. The magnetic field formed between two electrodes of the magnetic field means forming 200 has the part which produces the cyclotron resonance of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency magnetic field (1 or less KHZ) preferably 110 gauss or less more than 10 gauss (Gauss).

[0059] The magnetic field strength Bc (gauss) which produces cyclotron resonance has the relation of Bc=0.357xf (MHz) to the frequency f of the RF for plasma production (MHz) a well-known passage.

[0060] In addition, as long as two electrodes 12 and 15 in this invention have the substantially parallel electrode of the pair which carries out phase opposite, it is good and electrodes 12 and 15 may have some concave surface or convex from the demand of a plasma production property etc. In such 2 electrode molds, inter-electrode electric-field distribution can be equalized easily, and making generation of the plasma by cyclotron resonance into homogeneity has the comparatively easy description by improving the homogeneity of the magnetic field which intersects perpendicularly with this electric field.

[0061] The lower electrode 15 which carries out installation maintenance of the sample 40 has composition equipped with the electrostatic chuck 20 of 2 pole type. That is, the lower electrode 15 is constituted by outside 1st lower electrode 15A and 2nd lower electrode 15B arranged through an insulator 21 in the inside upper part, and the dielectric layer 22 for electrostatic adsorption (it is hereafter called an electrostatic adsorption film for short) is formed in the upper front face of the 1st and the 2nd car lower electrode. DC power supply 23 are connected to the 1st and the 2nd car lower inter-electrode one through the coils 24A and 24B for a high frequency component cut, and as the 2nd lower electrode 15B side just becomes, it impresses direct current voltage to both lower inter-electrode one. Thereby, according to the Coulomb force which acts on a sample 40 and both lower inter-electrode one through the electrostatic adsorption film 22, on the lower electrode 15, it adsorbs and a sample 40 is held. As an electrostatic adsorption film 22, dielectrics, such as what mixed the titanic-acid ghost, can be used for an aluminum oxide and an aluminum oxide, for example. Moreover, as a power source 23, the DC power supply of several 100 V are used.

[0062] Moreover, the pulse bias power supply 17 which supplies the pulse bias of the amplitude of 20V-1000V is connected to the lower electrode 15 (15A, 15B) through the blocking capacitors 19A and 19B which cut DC component, respectively.

[0063] Although explained until now, using 2 pole type as an electrostatic chuck, other electrostatic chucks, for example, a unipolar system and n pole type (n>=3), of a method are sufficient.

[0064] When performing etching processing, the sample 40 which is the object of processing is laid on the lower electrode 15 of the processing room 10, and is adsorbed by the electrostatic chuck 20. On the other hand, gas required for etching processing of a sample 40 is supplied to the processing room 10 through the gas induction room 34 from the gas supply section 36. Evacuation of the outside room 11 is carried out by the vacuum pump 18, and it is evacuated so that the processing room 10 may become the processing pressure force of a sample, for example, 0.4-4.0Pa, (pascal). Next, from RF generator 16, 50MHz - 200MHz high-frequency power is outputted desirably, and 30MHz - 300MHz of raw gas of the processing room 10 is plasma-ized.

[0065] Electronic cyclotron resonance is produced between the up electrode 12 and the lower electrode 15, it is 0.4-4.0Pa in low gas pressure, and the plasma of a high consistency is made to generate in this case by 30 thru/or 300MHz high-frequency power, and the part of the static magnetic field 10 gauss or more 110 gauss or less formed of the magnetic field means forming 200.

[0066] On the other hand, a period impresses the bias of 0.05-0.4 to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds on electrical potential differences 20V-1000V from the pulse bias power supply 17, the duty of a pulse part forward in 0.2 microseconds - 5 microseconds controls the electron and ion in the plasma, and etching processing to a sample 40 is performed.

[0067] After etching gas is made desired distribution with the gaseous diffusion plate 32, it is poured into the processing room 10 through the hole 38 which ended to the up electrode 12 and the up electrode covering 30.

[0068] Moreover, using the thing containing carbon, silicon, or these, a fluorine and an oxygen component are removed to the up electrode covering 30, and a selection ratio with the substrate of a resist, silicon, etc. is raised to it.
[0069] In order to raise the micro-processing nature of the sample of the diameter of macrostomia, it is good to attain stabilization of discharge in a low-gas-pressure field using the thing of the higher frequency as RF generator 16 for plasma generating. In this invention, it is the plasma consistency of 5x1010 thru/or 5x1011cm~3 by low voltage gas (0.4Pa thru/or 4Pa), and in order not to advance dissociation of gas too much but to acquire the uniform plasma with the diameter of macrostomia, RF generator 16 for plasma production is connected to the up electrode 12. On the other hand, the bias power supply 17 for ion energy control is connected to the lower electrode 15 which laid the sample, and distance between these two electrodes is set to 30 thru/or 100mm.
[0070] Moreover, 300MHz of electronic cyclotron resonance is preferably produced between the up electrode 12 and the lower electrode 15 10 gauss or more 110 gauss or less as RF generator 16 for plasma production by the interaction with the part of a static magnetic field 17 gauss or more 72 gauss or less or a low frequency (1kHz or less) magnetic field, 30MHz not being found and using VHF (50MHz thru/or 200MHz).
[0071] An example of the change of a plasma consistency when changing the frequency of the RF generator which generates the plasma, where the magnetic field which produces electronic cyclotron resonance is added to drawing 2 is shown. The pressure of the thing and processing room where sample offering gas added C4F8 to the argon 2 to 10% is 1Pa. The plasma consistency set the case of f= 2450MHz microwave ECR to 1, and has reference-value-ized it. In addition, the broken line shows the case where he has no magnetic field.
[0072] In 50 MHz<=f<=200MHz, a plasma consistency does not have about single figure compared with the case of microwave ECR, and falls about double figures. Moreover, dissociation of gas also falls and unnecessary fluorine atom / molecule, and generating of ion also fall single or more figures. Three or more [5x1010cm ~] processings of low-pressure and a high rate which the plasma with a high consistency is acquired moderately and are 0.4 to 4 Pa are attained as an absolute value of a plasma consistency the frequency of this VHF band, and by using cyclotron resonance. Furthermore, in order that dissociation of gas may not progress too much, either, a selection ratio with substrates, such as Si and SiN, is not greatly worsened to the insulator layer of SiO2 grade.
[0073] In 50 MHz<=f<=200MHz, although dissociation of gas progresses for a while compared with the 13.56MHz conventional parallel plate electrode, the fluorine atom / molecule by this, and the slight increment in ion can install the matter which contains silicon and carbon in an electrode surface or a chamber wall surface, and can improve. Or further, by adding bias to this electrode surface and chamber wall surface, a fluorine can be combined with carbon or silicon and can be discharged, or hydrogen and a fluorine are combined using the gas containing hydrogen, and it can discharge and improve.
[0074] If 200MHz or more of frequencies of an RF generator is set especially to 300MHz or more, a plasma consistency will become high, but since dissociation of gas becomes excessive, the increment in a fluorine atom / molecule, or ion becomes large too much and a selection ratio with substrates, such as Si and SiN, is worsened greatly, it is not desirable.
[0075] An electron shows the energy gain k acquired from RF electric field to drawing 3 at the time of cyclotron resonance and no resonating. Energy which an electron obtains in 1 period of a RF at the time of a non-magnetic field is set to e0, and it is a cyclotron-resonance magnetic field. Energy which an electron obtains in 1 period of a RF when Bc=2pif- (m/e) is impressed When referred to as e1, e1 and e0 become like several 1.
[0076]
[Equation 1]

$$e_0 = \frac{e^2 E^2}{2m}\left(\frac{\nu}{\omega^2+\nu^2}\right)$$

$$e_1 = \frac{e^2 E^2 D}{4m}\left(\frac{1}{\nu^2+(\omega-\omega c)^2}+\frac{1}{\nu^2+(\omega+\omega c)^2}\right) \cdots\cdots \text{数 1}$$

但し、Eは電界強度

[0077] k is expressed with a degree type when these ratios (= e1/e0) are set to k. However, m:mass of electrons, e:electronic charge, f: Impression frequency K= (nu2+omega2) (1/2) [1/(nu2+(omega-omegac) 2)+

(1/(nu2+(omega+omegac) 2))}
However, nu: Collision frequency omega[omega:excitation angular frequency and] c: The value of k becomes so large that a frequency is so high that gas pressure is low at general cyclotron angular frequency. Drawing 3 is the case of Ar (argon) gas, and is set to k>=150 by f>=50MHz in the pressure of P= 1Pa, and dissociation is promoted under low gas pressure compared with the time of there being no magnetic field. The cyclotron-resonance effectiveness becomes small quickly on the frequency of about 20MHz or less in the pressure of P= 1Pa. On the frequency of 30MHz or less, there are few cases where he has no magnetic field, and differences, and the cyclotron-resonance effectiveness is small so that it may understand also in the property shown in drawing 2 .
[0078] In addition, although the cyclotron-resonance effectiveness will increase if gas pressure is made low, in 1Pa or less, the electron temperature of the plasma increases and the opposite effect that dissociation progresses too much becomes large. In order to suppress too much dissociation of gas and to make a plasma consistency into about [5x1010cm ~ / 3 or more], 4Pa for about 1 to 4Pa is preferably good from 0.4Pa as a pressure of gas.
[0079] In order to demonstrate the cyclotron-resonance effectiveness, it is necessary to make the value of k or more into dozens. In order to use the cyclotron-resonance effectiveness effectively, without advancing dissociation of gas too much so that clearly also from drawing 2 or drawing 3 , by the pressure of 0.4Pa thru/or 4Pa, as an RF generator for plasma production, gas pressure does not have 30 and needs to use preferably 300MHz of 50 thru/or 200MHz VHF.
[0080] Drawing 4 shows variation deltaV of the ion acceleration voltage VDC by which induction is carried out to the sample when impressing 68MHz high-frequency power, and the induced voltage VDC in a sample while it grounds an up electrode by the conventional magnetron method chamber and gives the field B of a uniform longitudinal direction on a lower electrode. If the reinforcement of a magnetic field B is raised, the ion acceleration voltage VDC will become small according to the Lorentz force committed into an electron, and a plasma consistency will increase. However, in the case of the conventional magnetron discharge mold, since the reinforcement of a magnetic field B is as large as about 200 gauss, the homogeneity within the field of a plasma consistency gets worse, variation deltaV of induced voltage becomes large, and there is a fault in which the damage of a sample increases.
[0081] In order to make deltaV into or less 1 / five to 1/10 from drawing 4 compared with the case of 200 gauss of the conventional magnetron discharge mold, the reinforcement of a magnetic field B is [from / when it loses a damage in near a sample side that the small value of 15 gauss or less costs 30 gauss or less preferably] desirable.
[0082] A cyclotron-resonance field is the middle of the up electrode 12 and the lower electrode 15, and is formed in a mist and up electrode side from the mid-position of two electrodes. An axis of abscissa shows the distance from the sample side (lower electrode 15) to the up electrode 12, and, as for drawing 5 , the axis of ordinate shows the magnetic field. The examples of drawing 5 are conditions (impression frequency f1=100MHz, Bc=37.5G, and electrode spacing =50mm), and the ECR field is formed near 30mm from the sample side.
[0083] Thus, in this invention, the part which serves as max of a magnetic field component parallel to the lower electrode 15 (sample installation side) between the up electrode 12 and the lower electrode 15 is set to an up electrode surface or upper part [middle / of two electrodes] electrode side. By this, magnetic field strength parallel to the sample in a lower electrode surface is preferably made into 15 gauss or less 30 gauss or less, low RENTSUKA (ExB) which works into an electron near a lower electrode surface can be made into a small value, and generating of the heterogeneity within the field of the plasma consistency by the electronic drift condenser by low RENTSUKA in a lower electrode surface can be abolished.
[0084] According to the magnetic field means forming 200 of the example of drawing 1 , as shown in drawing 6 , an ECR field is formed in the location of the almost same height from the lower electrode 15 (sample installation side) except for near the center section of the sample. Therefore, uniform plasma treatment can be performed to the sample of the diameter of macrostomia. However, near the core of a sample, the ECR field is formed in the high location from the sample installation side. Since there is distance of 30mm or more between an ECR field and a sample base and ion and a radical trial are diffused and equalized between them, there is no problem in the usual plasma treatment. However, in order to carry out plasma treatment of the whole surface of a sample to homogeneity, it is desirable to be formed so that an ECR field may continue all over a sample and the ECR field of the outside of the location of the same height or a sample may become close to a sample base side a little rather than the ECR field near a core from a sample side. This cure is stated to a detail later.
[0085] As stated above, since dissociation of gas is advanced by the electron cyclotron resonance, using

30 thru/or 300MHz high-frequency power as RF generator 16 for plasma generating, in the example of this invention shown in drawing 1 , the plasma to which the gas pressure in the processing room 10 was stabilized by even the bottom of low voltage of 0.4Pa thru/or 4Pa is acquired. Moreover, since the collision of the ion in the inside of a sheath decreases, on the occasion of processing of a sample 40, the directivity of ion can increase and perpendicular micro-processing nature can be raised.

[0086] The perimeter of the processing room 10 makes min adhesion of the unnecessary deposit object to the part outside the ring 37 for [discharge ******] while aiming at improvement in ** and a plasma consistency to make the sample 40 neighborhood localize the plasma with the ring 37 for [discharge ******].

[0087] In addition, as a ring 37 for [discharge ******], semi-conductors and electric conduction material, such as carbon, silicon, or SiC, are used. If this ring 37 for [discharge ******] is connected to an RF generator and the spatter by ion is produced, while reducing depository adhesion to a ring 37, the removal effectiveness of a fluorine can also be given.

[0088] In addition, since a fluorine can be removed when performing plasma treatment using the gas which contains a fluorine for the insulator layer of SiO_2 grade if the susceptor covering 39 containing carbon, silicon, or these is formed on the insulator 13 of the circumference of a sample 40, it is useful to improvement in a selection ratio. In this case, if thickness of the insulator 13 for the lower part of the susceptor covering 39 is made thin to 0.5mm - about 5mm so that a part of power of bias power supply 17 may be impressed to the susceptor covering 39, the above-mentioned effectiveness will be promoted by the spatter effectiveness by ion.

[0089] Moreover, on both sides of the electrostatic adsorption film 22 of a dielectric, an electrostatic adsorption circuit is formed through the lower electrode 15 (15A, 15B) and a sample 40 of the potential of DC power supply 23. In this condition, according to electrostatic force, a sample 40 is stopped by the lower electrode 15 and held. Heat-conduction gas, such as helium, nitrogen, and an argon, is supplied to the rear face of the sample 40 stopped according to electrostatic force. Although the crevice of the lower electrode 15 is filled up with heat-conduction gas, the pressure is made into about thousands of pascals from hundreds of pascals. In addition, most electrostatic adsorption power is zero between the crevices in which the gap was prepared, and it can be considered that electrostatic adsorption power has occurred only in the heights of the lower electrode 15. However, since an electrical potential difference can be appropriately set as DC power supply 23 and the adsorption power which can bear the pressure of heat-conduction gas enough can be set up so that it may state later, a sample 40 moves by heat-conduction gas, or it is not flown.

[0090] By the way, the electrostatic adsorption film 22 acts so that a bias operation of the pulse bias to the ion in the plasma may be reduced. It is not actualizing, although this operation is produced also by the conventional approach which is carrying out bias using the sinusoidal power source. However, on the pulse bias, since the description that ion ENEGI width of face is narrow falls victim, a problem becomes large.

[0091] In this invention, in order to control the rise of the electrical potential difference generated among the both ends of the electrostatic adsorption film 22 with impression of pulse bias and to heighten the effectiveness of pulse bias, one description is to have established the electrical-potential-difference control means.

[0092] It is good to constitute so that change (VCM) of the electrical potential difference in a round term of the bias voltage produced among the both ends of an electrostatic adsorption film with impression of pulse bias as an example of an electrical-potential-difference control means may become 1/2 or less [of the magnitude (****) of pulse bias voltage]. There is a method of increasing the electrostatic capacity of a dielectric by making thin thickness of the electrostatic adsorption film which specifically consists of a dielectric prepared in the front face of the lower electrode 15, or using a dielectric as an ingredient with a large dielectric constant.

[0093] Or there is also the approach of shortening the period of pulse bias voltage and controlling the rise of an electrical potential difference VCM as other electrical-potential-difference control means, again. Furthermore, the method of separating into another location, for example, electrode with a sample another [the electrode by which arrangement maintenance is carried out] which counters, or the third electrode prepared independently, and preparing an electrostatic adsorption circuit and a pulse bias voltage impression circuit is also considered.

[0094] Next, change (VCM) of an electrical potential difference and the relation of pulse bias voltage which are produced among the both ends of the electrostatic adsorption film in a pulse bias round term which should be brought about by the electrical-potential-difference control means in this invention are stated to a detail using drawing 7 - drawing 13 .

[0095] First, the desirable example of an output wave used in the pulse bias power supply 17 of this invention is shown in drawing 7 . Inside of drawing, pulse amplitude: vp, Pulse period:T0 and forward direction pulse width:T1 It carries out.
[0096] When the wave of drawing 7 (A) is impressed to a sample via a blocking capacitor and the dielectric layer for electrostatic adsorption (it is hereafter called an electrostatic adsorption film for short), the potential wave on the front face of a sample in the steady state in the condition of having generated the plasma according to another power source is shown in drawing 7 (B).
however, wave-like dc-component electrical potential difference : floating potential [of the VDC plasma]: -- maximum electrical-potential-difference [in a round term of the electrical potential difference produced among the both ends of Vf electrostatic adsorption film]: -- it is referred to as VCM.
[0097] The inside of drawing 7 (B), and Vf The becoming part (I) I [used as a forward electrical potential difference] Is a part which has mainly drawn only the electron current, and it is Vf. A negative part is the part which has drawn the ion current, and Vf. A part is a part (Vf is usually severalV-about tenv) which an electron and ion hang and suit.
[0098] In addition, in explanation of drawing 7 (A) and future, the capacity of a blocking capacitor and the capacity by the insulator of the sample surface neighborhood assume that it is sufficiently large compared with the capacity (it is called electrostatic adsorption capacity for short below) by the electrostatic adsorption film. The value of VCM is expressed with the following formula (several 2).
[0099]
[Equation 2]

$$V_{CM} = \frac{q}{c} = \frac{i_i \times (T_0 - T_1)}{(\varepsilon_r \varepsilon_0 / d) \times K} \quad \cdots\cdots \text{数}2$$

[0100] However, q: (T0-T1) The ion current consistency which flows into a sample at a period (average)
c: Electrostatic adsorption capacity per unit area (average)
ii : ion current consistency epsilonr : Specific inductive capacity d of an electrostatic adsorption film: Thickness of an electrostatic adsorption film epsilon 0 : Dielectric constant in a vacuum (constant)
K: Electrode coverage of an electrostatic adsorption film (<=1)
To drawing 8 and drawing 9 , pulse duty ratio: (T1/T0) is T0, while it is fixed. The potential wave on the front face of a sample at the time of making it change and the probability distribution of ion energy are shown. However, it is referred to as T01 and T02:T03:T04:T05=16:8:4:2:1.
[0101] As shown in (1) of drawing 8 , it is the pulse period T0. If too large, it separates from the potential wave on the front face of a sample greatly from a square wave, and it becomes a triangular wave, and as shown in drawing 9 , it becomes fixed distribution and is not desirable [ion energy] to the higher one from the lower one.
[0102] As shown in (2) - (5) of drawing 8 , it is the pulse period T0. (VCM/vp) serves as a value smaller than 1, and ion energy distribution also becomes narrow as it is made small.
[0103] drawing 8 and drawing 9 -- setting -- T0=T01, and TO02, T03, T04 and T -- 05= (VCM/vp) 1, 0.63, 0.31, and 0. -- 16 and 0.08 are supported. Next, the relation of the maximum electrical potential difference VCM in a round term of the electrical potential difference produced between the OFF (T0-T1) period of a pulse and the both ends of an electrostatic adsorption film is shown in drawing 10 .
[0104] When the coat of about 50% of an electrode (K= 0.5) is carried out using a titanium oxide content alumina (epsilonr=10) with a thickness of 0.3mm as an electrostatic adsorption film, it is ion current consistency ii =5 mA/cm2. The thick wire (line of standard conditions) of drawing 10 shows the value change of VCM in the inside of the semi-gross density plasma.
[0105] The electrical potential difference VCM produced among the both ends of an electrostatic adsorption film as the OFF (T0-T1) period of a pulse becomes large so that clearly from drawing 10 is the pulse voltage vp which serves as a big value in proportion to it, and is usually used. It will become above.
[0106] For example, it sets to a plasma etching system and is usually by gate etching by selectivity with a damage, a substrate, or a mask, a configuration, etc. By 20volt <= vp <=100volt metal etching By 50volt <= vp <=200volt oxide film etching It is restricted to 250volt <= vp <=1000volt.
[0107] When it is going to fulfill the below-mentioned conditions of <=(VCM/vp) 0.5, in reference condition, the upper limit of (T0-T1) is as follows.
By gate etching (T0-T1) By <=0.15-microsecond metal etching (T0-T1) By <=0.35-microsecond oxide film etching (T0-T1) T0 is 0.1 microseconds at <=1.2microsecond and time. If it becomes near, since the impedance of an ion sheath will approach the impedance of the plasma or will become less than [it], while producing generating of the unnecessary plasma, bias power supply is no longer used effective in

acceleration of ion. For this reason, since the controllability of the ion energy by bias power supply gets worse, T0 has 0.2 preferably good microseconds or more 0.1 microseconds or more.
[0108] Therefore, vp In the gate etcher pressed down low, withstand voltage is not reduced, and it is thin, for example, it necessary for specific inductive capacity to change the ingredient of an electrostatic adsorption film into 10-100, and a high thing (for it to be epsilonr =25 at Ta 2O3), or to set desirably 10 micrometers - 400 micrometers of thickness to 10 micrometers - 100 micrometers.
[0109] In drawing 10 , the value of VCM at the time of making the electrostatic capacity c per unit area increase by 2.5 times, 5 times, and 10 times, respectively was also written together. Even if it improves an electrostatic adsorption film, if the improvement which increases electrostatic capacity c several times is regarded as a limit and sets to VCM<=300 volt and c<=10c0, 0.1microsecond<=(T0-T1) <=10microsecond will come in the present condition. A part effective in plasma treatment is a part of (T0-T1) by acceleration of ion, and the smaller possible one as pulse duty (T1/T0) is desirable.
[0110] It is drawing 11 which was estimated by (VDC/vp) as effectiveness of plasma treatment which also considered the time average. It is desirable to make (T1/T0) small, and to enlarge (VDC/vp).
[0111] If 0.5 <= (VDC/vp) is assumed as effectiveness of plasma treatment and the below-mentioned conditions and <=(VCM/vp) 0.5 are put in, pulse DEYUDI will become about <=(T1/T0) 0.4.
[0112] In addition, although pulse DEYUDI (T1/T0) is so effective in control of ion energy that it is small, if it is made small beyond the need, pulse width T1 will serve as a small value which is about 0.05 microseconds, and separation with a high frequency component for plasma generating which comes to contain many dozens of MHz frequency components, and mentions them later also becomes difficult. As shown in drawing 11 , the falls of (VDC/vp) between 0 <=(T1/T0) <=0.05 are few, and especially a problem is not produced or more in 0.05 as (T1/T0).
[0113] Here shows the ion energy dependency of the etching rates ESi and ESiO2 of the silicon when plasma-izing chlorine gas 1.3Pa, and the oxide film of a substrate as an example of gate etching to drawing 12 . The etching rate ESi of silicon becomes constant value in low ion energy. Ion energy also increases ESi according to the increment in ion energy beyond about 10V. Ion energy is 0 or less about 20V, and if about 20V is exceeded, ESiO2 will increase the etching rate ESiO2 of the oxide film which serves as a substrate on the other hand with ion energy.
[0114] Consequently, the field where selection-ratio ESi/ESiO2 with a substrate becomes [ion energy] infinity or less about 20V exists. As for selection-ratio ESi/ESiO2 with a substrate, ion energy falls quickly with the increment in ion energy beyond about 20V.
[0115] ethyne great of an oxide film and silicon when drawing 13 plasma-izes C4F8 gas 1.0Pa as an example of etching of the oxide films (SiO2, BPSG, HISO, etc.) which are kinds of an insulator layer -- ion energy distribution of ESiO2 and ESi is shown.
[0116] In low ion energy, the etching rate ESiO2 of an oxide film serves as a negative value, and produces a depository. In the 400V neighborhood, ESiO2 just starts quickly and ion energy increases gradually after that. The etching rate ESi of the silicon which serves as a substrate on the other hand serves as (+) and (etching) from (-) and (etching), and increases from ESiO2 gradually in the high place of ion energy.
[0117] Consequently, the selection ratios ESiO2/ESi with a substrate in the neighborhood which changes from (-) to (+) infinity It becomes and ESiO2/ESi falls quickly with the increment in ion energy more than by it. [ESiO2]
[0118] To application in an actual process, in consideration of ESi, the value of ESiO2, ESi/ESiO2, and the magnitude of the value of ESiO2/ESi, bias power supply is adjusted and ion energy is made into a proper value by drawing 12 and drawing 13 .
[0119] Moreover, just etching (etching until the substrate film appears) gives priority to the magnitude of an etching rate, and just, if after dirty gives priority to the magnitude of a selection ratio and ion energy is just changed into dirty order, a still better property will be acquired.
[0120] By the way, the property shown in drawing 12 and drawing 13 is a property when the energy distribution of ion is limited to a narrow part. Since each etching rate when the energy distribution of ion is large serves as the time average value, it will not be able to be set as an optimum value but a selection ratio will fall sharply.
[0121] According to the experiment, when (VDC/vp) was or less 0.3 extent, the breadth of ion energy became about **15% or less, and 30 or more high selection ratios were obtained also in the property of drawing 12 or drawing 13 . Moreover, when it was <=(VDC/vp) 0.5, the improvement of a selection ratio etc. was able to be aimed at compared with the conventional sinusoidal bias method.
[0122] thus, as an electrical-potential-difference control means to suppress the electrical-potential-difference change (VCM) during a round term of the pulse voltage produced among the both ends of an

electrostatic adsorption film That VCM constitutes so that it may become 1/2 or less [of the magnitude vp of pulse bias voltage] often and specifically The capacity of a dielectric can be increased by making thin thickness of the electrostatic chuck film 22 of the dielectric prepared in the front face of the lower electrode 15, or using a dielectric as an ingredient with a large dielectric constant. Or the period of pulse bias voltage is made it is desirable and as short as 0.2 microseconds - 5 microseconds (repeat frequency: correspond to 0.2MHz - 5MHz) for 0.1 microseconds to 10 microseconds, and electrical-potential-difference change of the both ends of an electrostatic adsorption film is controlled for pulse DEYUDI (T1/T0) as 0.05 <=(T1/T0) <==0.4.
[0123] Or you may make it fulfill the conditions of <=(VCM/vp) 0.5 which change of the electrical potential difference VCM produced among the both ends of an electrostatic adsorption film described above again combining some of thickness of the electrostatic adsorption film of the above-mentioned dielectric, specific inductive capacity of a dielectric, and periods of pulse bias voltage.
[0124] Next, the example which used the vacuum processing room of drawing 1 for etching of insulator layers (for example, SiO2, SiN, BPSG, etc.) is described.
[0125] As gas, the thing of a presentation of CO:10 - 20%, is used C4F8:1-5%, Ar:90-95%, O2:0-5% or C4F8:1-5%, Ar:70-90%, and O2:0-5%. As RF generator 16 for plasma generating, stabilization of discharge in a 1-3Pa low-gas-pressure field is measured using a frequency higher than before, for example, a 40MHz thing.
[0126] In addition, when dissociation beyond the need advances by RF-ization of RF generator 16 for the sources of the plasma, the output of RF generator 16 is turned on and off or level modulation controlled by the source 161 of an RF generator modulating signal. At the time of a high level, generation of ion prospers compared with generation of a radical, and when it is a low, generation of a radical prospers compared with generation of ion. As ON (or high level at time of level modulation) time amount, 20 microseconds - about 150 microseconds of periods are used for 10 to 100 microseconds about 5 to 50 microseconds as off time amount (or low at the time of a level modulation). While this prevents unnecessary dissociation, a desired ion-radical ratio can be obtained.
[0127] Moreover, the modulation period of the RF generator for the sources of the plasma usually becomes long compared with the period of pulse bias. Then, the improvement of a selection ratio was completed by making the modulation period of the RF generator for the sources of the plasma into the integral multiple of the period of pulse bias, and optimizing the phase between two.
[0128] On the other hand, impression of pulse bias voltage performs the ion in the plasma, and ion energy is controlled acceleration and by making it put perpendicular ON in a sample. As pulse bias power supply 17, by using the power source of pulse amplitude:****=800V pulse period:T=0.65microsecond and pulse width:T1=0.15microsecond, the distribution width of face of ion energy became **15% or less, and the plasma treatment with the sufficient property of 20-50 as Si of a substrate or a selection ratio with SiN became possible.
[0129] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 14 is explained. Although this example is the same configuration, it differs from having been shown in drawing 1 in that the lower electrode 15 holding a sample 40 has composition equipped with the electrostatic chuck 20 of a unipolar system. The dielectric layer 22 for electrostatic adsorption is formed in the upper front face of the lower electrode 15, and the plus side of DC power supply 23 is connected to the lower electrode 15 through the coil 24 for a high frequency component cut. Moreover, the pulse bias power supply 17 which supplies the forward pulse bias of 20V-1000V is connected through the blocking capacitor 19.
[0130] While installing the rings 37A and 37B for [discharge ******] in the perimeter of the processing room 10 and aiming at improvement in a plasma consistency, adhesion of the unnecessary deposit object to the part besides ring 37for [discharge ******] A and 37B is made into min. In the rings 37A and 37B of drawing 14 for [discharge ******], the diameter of the soil hand part of ring 37A for [discharge ******] by the side of a lower electrode is made smaller than the diameter of the soil hand part of ring 37B for [discharge ******] by the side of an up electrode, and makes distribution of the resultant in the sample circumference uniform.
[0131] In addition, semi-conductors and conductors, such as carbon, silicon, or SiC, are used for the side which faces a processing room side at least as an ingredient of the rings 37A and 37B for [discharge ******]. Moreover, 100K-13.56MHz bias-power-supply 17A for discharge ****** rings is connected to lower electrode side ring 37A through capacitor 19A, it constitutes like, and while reducing depository adhesion to the rings 37A and 37B by the spatter effectiveness of ion for which a part of power of the high periphery power source 16 is impressed to up electrode side ring 37B, the removal effectiveness of a

fluorine is also given.
[0132] In addition, 13A and 13C of drawing 14 are an insulator which consists of aluminas etc., and 13B is an insulator which has conductivity, such as SiC, glassy carbon, and Si.
[0133] when the conductivity of Rings 37A and 37B is low, conductors, such as a metal, are built in in ring 37A and 37B -- making -- the front face of a ring, and internal organs -- by narrowing distance of a conductor, high-frequency power can carry out that it is easy to emanate from the front face of Rings 37A and 37B, and can heighten the spatter effectiveness.
[0134] As for the up electrode covering 30, only the circumference is usually fixed to the up electrode 12 with a bolt 250. Gas is supplied to the up electrode covering 30 through the gas induction room 34, the gaseous diffusion plate 32, and the up electrode 12 from the gas supply section 36. In order that the hole prepared in the up electrode covering 30 may make abnormality discharge in a hole hard to generate, it is the pore of the diameter of 0.3-1mm, and the gas pressure of the up electrode covering 30 upper part becomes several [of one atmospheric pressure / 1/] to about 1/10. For example, the force about 100kg or more is added as a whole to the up electrode covering 30 of the diameter of 300mm. For this reason, the up electrode covering 30 becomes convex to the up electrode 12, and produces a clearance hundreds of microns or more near a center section.
[0135] In this case, if about 30MHz or more of frequencies of the source 16 of high frequency becomes high, the phenomenon in which it becomes impossible to disregard longitudinal direction resistance of the up electrode covering 30, and the plasma consistency near a center section falls especially will come out. What is necessary is just to fix the up electrode covering 30 to the up electrode 12 by main approach other than the circumference, in order to improve this. In the example of drawing 14 , with the bolt 251 of insulators, such as semi-conductors, such as SiC and carbon, or an alumina, several places of the main approach of the up electrode covering 30 are fixed to the up electrode 12, and distribution of the RF impressed from the up electrode 12 side is made uniform.
[0136] In addition, the approach of the up electrode covering 30 which fixes a main approach part to the up electrode 12 at least is not limited to the above-mentioned bolt 251 at all, is the whole surface about the up electrode covering 30 and the up electrode 12 by the matter with an adhesion operation, or may be pasted up in the part of main approach at least.
[0137] In the example of drawing 14 , the sample 40 which is the object of processing is laid on the lower electrode 15, and is adsorbed according to the Coulomb force produced among the both ends of the electrostatic adsorption film 22 with the positive charge by the electrostatic chuck 20 23, i.e., DC power supply, and the negative charge supplied from the plasma.
[0138] An operation of this equipment evacuates the pressure of the processing room 10 to the processing pressure force of a sample, and 0.5-4.0Pa by carrying out evacuation with the another side vacuum pump 18, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing [are the same as that of the plasma etching system of 2 electrode molds shown in drawing 1 ,] raw gas into the processing room 10 by the predetermined flow rate from a gas supply system 36, when performing etching processing. Next, RF generator 16 is set to ON, between two electrodes 12 and 15, the high-frequency voltage of 30MHz - 100MHz is impressed preferably, and 20MHz - 500MHz of plasma is generated. On the other hand, 20V-1000V, and a period impress the forward pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds from the pulse bias power supply 17, the plasma in the processing room 10 is controlled, and etching processing is performed in a sample 40.
[0139] impression of such pulse bias voltage -- the ion in the plasma, or ion -- and -- and highly precise configuration control or selection-ratio control is performed for an electron in a sample acceleration and by making it put perpendicular ON. The property required for the pulse bias power supply 17 and the electrostatic adsorption film 22 is the same as that of the example of drawing 1 , and is omitted for details.
[0140] Next, drawing 15 thru/or drawing 17 explain other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 1 , the configurations of the magnetic field means forming 200 differ. Eccentricity of the core 201 of the magnetic field means forming 200 is carried out, and it is constituted so that it may drive by the motor 204 centering on the shaft equivalent to the center position of a sample 40 and may rotate at the rate of the number of per minute thru/or dozens rotations. In addition, the core 201 is grounded. In order to carry out plasma treatment of the whole surface of a sample with high precision, compared with near the center section of the sample, it is good to enlarge the electronic cyclotron-resonance effectiveness on a periphery or its outside compared with a center so that generation of the periphery of a sample or the plasma near [the] an outside may increase. However, in the case of the example of drawing 1 , as shown in drawing 6 , near

the core of a sample, there is no ECR field and the case where a plasma consistency becomes low too much near a core comes out.
[0141] In the example of drawing 15 , when the core 201 the magnetic field means forming 200 carried out [the core] eccentricity rotates, distribution of a magnetic field changes, and near the core of a sample, an ECR field is formed in a low location from a sample side, and is formed in a location high from a sample side at time-of-day t=1/2T0 by time of day t= 0 and t=T0. As a result of a core's 201 rotating at the rate of the number of per minute thru/or dozens rotations, as shown in drawing 17 , the average of the magnetic field strength of a direction parallel to the sample side in the pars intermedia of two electrodes turns into the almost same value by time average-ization by rotation. That is, an ECR field is formed in the location of the almost same height from a sample side except for the periphery of a sample.
[0142] In addition, as the alternate long and short dash line showed in the core 201 section of drawing 15 , the core which constitutes the magnetic circuit of the side near the core of the center section which carried out eccentricity is thin in the thickness, and if the core which constitutes the magnetic circuit of a far side thickens the thickness, the homogeneity of magnetic field strength will improve further.
[0143] Next, drawing 18 thru/or drawing 19 explain other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 15 , the configurations of the magnetic field means forming 200 differ. The core 201 of the magnetic field means forming 200 has concave edge 201A in the location corresponding to the center of a processing room, and has edge 201B besides the side location of a processing room. According to an operation of concave edge 201A, magnetic flux B has the inclined direction component. Consequently, distribution of a magnetic field changes, and as shown in drawing 19 , compared with the case where the magnetic field strength of a component parallel to a sample side is the example of drawing 1 , it is equalized more.
[0144] Next, drawing 20 explains other examples of this invention. Although this example is the same configuration as the plasma etching system of 2 electrode molds shown in drawing 15 , the configurations of the magnetic field means forming 200 differ. The core 201 of the magnetic field means forming 200 is fixed, and constitutes a magnetic circuit with the core 205 arranged in the location corresponding to the center of a processing room. A core 205 rotates the surroundings of the shaft which passes along the core of edge 201A with an insulator 203. Of such a configuration, the average location of the ECR field in near the core of a sample is formed in the almost same location from a sample side like the example of drawing 15 . That is, an ECR field continues all over a sample and is formed in the location of the almost same height from a sample side.
[0145] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 21 thru/or drawing 22 is explained. The magnetic field means forming 200 equips the perimeter of the processing room 10 with two pairs of coils 210,220, and by changing the sense of the field which can be put on the coil of each set one by one like arrow heads 1, 2, 3, and 4, it consists of this example so that rotating magnetic field may be formed. Center position O-O of a coil 210,220 is located in the upper part [middle / of two electrodes 12 and 15] electrode 12 side. 30 gauss or less, this constitutes the magnetic field strength on a sample 40 so that it may become 15 gauss or less preferably. By selecting the location of a coil 210,220, and an outer diameter suitably, the intensity distribution of a magnetic field can be adjusted so that generation of the periphery of a sample or the plasma near [the] an outside may increase more.
[0146] Next, drawing 23 and drawing 24 explain the plasma etching system of 2 electrode molds which become other examples of this invention. In this example, it has coil 210' of the pair arranged in the shape of radii in a horizontal plane along the perimeter of the circular processing room 10 as magnetic field means forming 200. The current which flows to coil 210' of this pair is controlled, and as an arrow head (1) and (2) showed, the polarity of a magnetic field is changed to drawing 23 for every fixed period.
[0147] As a broken line shows to drawing 24 , since magnetic flux B spreads in a processing room core in a vertical plane, the magnetic field strength of a processing room core falls. However, since coil 210' of a pair is curved along a processing room, in a horizontal plane, magnetic flux B gathers in a processing room core. Therefore, the magnetic field strength of a processing room core can be raised compared with the example of drawing 22 . That is, in the example of drawing 23 , compared with the example of drawing 22 , the fall of the magnetic field strength in a processing room core can be controlled, and the homogeneity of the magnetic field strength in the sample installation side of a sample base can be raised.
[0148] Moreover, the drift condenser of ExB is lessened by changing the polarity of a magnetic field for every fixed period.
[0149] In addition, two pairs of the same coils as the example of drawing 22 may be adopted as magnetic field means forming 200.

[0150] moreover -- a magnetic field -- means forming -- 200 -- ****** -- circular -- a coil -- 210 -- ' -- replacing with -- drawing 25 -- being shown -- as -- being circular -- processing -- a room -- ten -- a perimeter -- meeting -- arranging -- having had -- plurality -- a straight line -- a coil -- a part -- combination -- becoming -- a convex -- type -- a coil -- 210 -- ' -- ****** -- being good . Also in this case, in a horizontal plane, magnetic flux B comes to gather in a processing room core, and the same effectiveness as the example of drawing 23 is acquired.
[0151] Furthermore, like the example of drawing 26 , the medial axis of one pair of coils is made to incline in a vertical plane, and may be arranged so that a sample side may be approached in a processing room core. Since according to this example the magnetic field strength of a processing room core can be raised and the magnetic field strength of a processing room periphery can be lowered, the homogeneity of the magnetic field strength in the sample installation side of a sample base can be raised. In addition, for equalization of magnetic field strength, it is good to make theta into the range of 5 times thru/or 25 degrees whenever [tilt-angle / of the medial axis of a coil].
[0152] Moreover, as shown in drawing 27 , by installing coil 210B and controlling the current of 2 sets of coils near the coil 210A of a pair, with an ECR resonance location, the inclination of the magnetic field near an ECR resonance location can be changed, and the width of face of an ECR resonance region can also be changed. By optimizing the width of face of an ECR resonance region for every process, it becomes possible to obtain the ion / radical ratio suitable for each process.
[0153] In addition, the homogeneity of magnetic-field-strength distribution and the control characteristic can be further raised by combining suitably the example of drawing 23 thru/or drawing 27 described above if needed.
[0154] Next, the plasma etching system of 2 electrode molds which become other examples of this invention by drawing 28 thru/or drawing 29 is explained. In this example, while a part of processing interior wall consists of conductors, it is grounded. On the other hand, the magnetic field means forming 200 equips the perimeter and the upper part of the processing room 10 with the coil 230,240. As an arrow head shows, the sense of the magnetic flux B formed with a coil 230 and the sense of magnetic-flux B' formed with a coil 230 consist of denial **** and circumference ****** of the processing room 10 mutually in the core of the processing room 10 so that it may superimpose mutually. Consequently, the intensity distribution of the magnetic field on a sample side become like drawing 29 . And in a part for the installation surface part of a sample 40, the sense of the electric-field component between the up electrode 12 and the lower electrode 15 and the sense of a field component are parallel. On the other hand, in the lateral part of the installation side of a sample 40, it is the periphery of the up electrode 12, or the part of the up electrode 12 and a processing interior wall, and the field component of the lengthwise direction which intersects perpendicularly with a lateral electric-field component arises.
[0155] therefore, the example of drawing 28 -- getting twisted -- the cyclotron-resonance effectiveness of the electron in near the core of a sample can be lowered, and generation of the periphery of a sample or the plasma near [the] an outside can be raised. Thus, plasma density distribution can be equalized by raising more generation of the periphery of a sample, or the plasma near [the] an outside.
[0156] Next, drawing 30 explains other examples of this invention. this example impresses the high frequency f3 about 1MHz or less to the up electrode 12 as bias from the low frequency power source 163, when ion energy sufficient in the high-frequency power f1 impressed to the up electrode 12 is not obtained from RF generator 16 in the plasma etching system of 2 electrode molds shown in drawing 1 -- ion energy -- 100-200 -- it is made to increase about by V In addition, 164,165 is a filter.
[0157] Next, drawing 31 explains the example of this invention in the plasma etching system of 2 electrode molds of a non-magnetic field mold.
[0158] As stated above, in order to raise the micro-processing nature of a sample, it is good to measure stabilization of discharge in a low-gas-pressure field using the thing of the higher frequency as RF generator 16 for plasma generating. In the example of this invention, the processing pressure force of the sample in the processing room 10 is set to 0.5-4.0Pa. Since the collision of the ion in the inside of a sheath decreased by making gas pressure in the processing room 10 into the low voltage of 40 or less mTorrs, on the occasion of processing of a sample 40, the directivity of ion increased and perpendicular micro processing became possible. In addition, in 5 or less mTorrs, in order to obtain the same processing speed, while an exhauster and an RF generator are enlarged, dissociation beyond the need of being based on the rise of electron temperature arises, and there is an inclination for a property to deteriorate.
[0159] Generally, the relation between the frequency of the power source for plasma generating using two electrodes of a pair and the minimum gas pressure with which discharge is given to a stabilization target that the stable discharge minimum gas pressure falls is, so that the frequency of a power source becomes

high and inter-electrode distance becomes large, as shown in drawing 32 . In order to operate effectively the effectiveness of avoiding bad influences, such as a surrounding wall and a depository to the discharge confinement ring 37, and removing the fluorine and oxygen by the up electrode covering 30, the susceptor covering 39, the resist in a sample, etc., it is desirable to set inter-electrode distance to about 50mm or less corresponding to 25 or less times of the average free process at the time of highest gas pressure 40mTorr. Moreover, as an inter-electrode distance, if it is not more than two to 4 time (4mm - 8mm) extent of the average free process at the time of the highest gas pressure (40mTorr), stable discharge will become difficult.

[0160] In the example shown in drawing 31 , in order to use 30MHz - 200MHz high-frequency power desirably, even if it makes 20MHz - 500MHz of gas pressure of the processing interior of a room into the low voltage of 0.5-4.0Pa as RF generator 16 for plasma generating, the stable plasma is acquired and micro-processing nature can be raised. Moreover, by using such high-frequency power, dissociation of the gas plasma becomes good and the selection-ratio control at the time of sample processing becomes good.

[0161] In the example of this invention described above, possibility that interference will arise between the output of pulse bias power supply and the output of the power source for plasma generating is also considered. Then, this cure is described hereafter.

[0162] First, pulse-width:T1, a pulse period: In the ideal rectangular pulse which has the standup / falling rate of infinity by T0, as shown in drawing 33 , f<=3f of about 70 - 80% of power is contained in the frequency range of 0 (f0= (1/T1)). Since the wave actually impressed starts and becomes limited [a /falling rate], the convergency of power improves further and f<=3f of about 90% or more of power can be contained in the frequency range of 0.

[0163] 3f0 It is 0 f<=3f to 3f0 which prepares a counterelectrode almost parallel to a sample and can be found in the-three number of degree types in order for pulse bias with a high frequency component to be made to be impressed in a sample side by homogeneity. It is desirable to ground the frequency component of the range.

[0164]

[Equation 3]

$$T_1=0.2\,\mu s \text{とすると}\quad 3f_0=3\cdot\frac{10^6}{0.2}=15\text{MHz}$$

$$T_1=0.1\,\mu s \text{とすると}\quad 3f_0=30\text{MHz} \qquad \cdots\cdots \text{数 3}$$

[0165] The example shown in drawing 31 is coping with interference with the above-mentioned pulse bias-power-supply output and the power outlet for plasma generating. That is, in this plasma etching system, RF generator 16 for plasma generating is connected to a sample 40 and the up electrode 12 which counters. In order to make the section electrode 12 into the touch-down level of pulse bias besides, it is the frequency f1 of RF generator 16 for plasma generating. Above 3f0 It enlarges and is f=f1. The impedance in the neighborhood is large and the band eliminator 141 with a low impedance is connected between the up electrode 12 and touch-down level on other frequencies.

[0166] On the other hand, it is f=f1. The impedance in the neighborhood is low and other frequencies install the band pass filter 142 with a high impedance between the sample base 15 and touch-down level. If such a configuration is used, interference between the output of the pulse bias power supply 17 and power-source 16 output for plasma generating can be suppressed on satisfactory level, and good bias can be added to a sample 40.

[0167] Drawing 34 is the example which is an inductive-coupling mold discharge method among external energy supply discharge methods, and applied this invention to the non-magnetic field type plasma etching system. It is the RF generator to which 52 impresses a flat-surface coil to a flat-surface coil, and 54 impresses the high-frequency voltage of 10MHz - 250MHz. Compared with the method having shown the inductive-coupling mold discharge method in drawing 10 , it is a low frequency and low voltage and stable plasma generating are attained. On the contrary, since dissociation becomes easy to progress, as drawing 1 showed, the output of RF generator 1 can be modulated by the source 161 of an RF generator modulating signal, and unnecessary dissociation can be prevented. The processing room 10 as a vacuum housing is equipped with the sample base 15 where a sample 40 is laid on the electrostatic adsorption film 22.

[0168] When performing etching processing, the pressure of the processing room 10 is evacuated to 0.5-4.0Pa by carrying out evacuation with an another side vacuum pump, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing raw gas into the processing room 10 by the predetermined flow rate from a gas supply system (not shown). Next, the high-frequency

voltage of 13.56MHz is applied to RF generator 54, and the processing room 10 is made to generate the plasma. Etching processing of the sample 40 is carried out using this plasma. On the other hand, at the time of etching, a period impresses the pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds. It is as the amplitude of pulse bias voltage having stated that the range changes with membrane types in the example of drawing 1 . Impression of this pulse bias voltage performs the ion in the plasma, and highly precise configuration control or selection-ratio control is performed in a sample acceleration and by making it put perpendicular ON. Thereby, even if the resist mask pattern of a sample is very detailed, highly precise etching processing can be performed.

[0169] Moreover, as shown in drawing 35 , in an inductive-coupling mold discharge method non-magnetic field type plasma etching system, the Faraday shield plate 53 which has a clearance in the processing room 10 side of an induction ******** output, and the 0.5mm - 5mm thin electric insulating plate 54 for shielding plate protection may be installed, and the Faraday shield plate may be grounded. While decreasing the capacity component between a coil and the plasma, being able to fall the energy of ion which strikes the quartz plate under the coil 52 in drawing 34 , and the electric insulating plate 54 for shielding plate protection and lessening damage on a quartz plate or an electric insulating plate by installation of the Faraday shield plate 53, mixing of the foreign matter to the inside of the plasma can be prevented.

[0170] Moreover, since the Faraday shield plate 53 serves also as the duty of the earth electrode of the pulse bias power supply 17, it can impress pulse bias to homogeneity between a sample 40 and the Faraday shield plate 53. In this case, the filter installed in an up electrode or the sample base 15 is unnecessary.

[0171] Drawing 36 is the front view which carried out the longitudinal section of some equipments which applied this invention to microwave plasma treatment equipment. The pulse bias power supply 17 and DC power supply 13 are connected to the lower electrode 15 as a sample base 15 where a sample 40 is laid on the electrostatic adsorption film 22. 41 is a magnetron as a source of an oscillation of microwave, 42 is the waveguide of microwave, and 43 is a quartz plate for carrying out the vacuum lock of the processing room 10, and supplying microwave to the processing room 10. The first solenoid coil with which 47 supplies a magnetic field, and 48 are the second solenoid coil which supplies a magnetic field. 49 is a raw gas supply system and supplies the raw gas which processes etching, membrane formation, etc. in the processing room 10. Moreover, evacuation of the processing room 10 is carried out by the vacuum pump (not shown). The property required for the pulse bias power supply 17 and the electrostatic chuck 20 is the same as that of the example of drawing 1 , and is omitted for details.

[0172] When performing etching processing, the pressure of the processing room 10 is evacuated to 0.5-4.0Pa by carrying out evacuation with an another side vacuum pump, laying the sample 40 which should process in the sample base 15, holding by electrostatic force, and introducing raw gas into the processing room 10 by the predetermined flow rate from a gas supply system 49. Next, the second solenoid coil 47 and 48 is set to ON, and the processing room 10 is made to generate ******** and the plasma for the microwave generated in the magnetron 41 from a waveguide 42 a magnetron 41 and for a start. Etching processing is performed in a sample 40 using this plasma. On the other hand, at the time of etching, a period impresses the pulse bias voltage for 0.2 microseconds - 5 microseconds to the lower electrode 15 preferably for 0.1 microseconds to 10 microseconds.

[0173] Highly precise configuration control or selection-ratio control is performed by accelerating in a sample and carrying out incidence of the ion in the plasma perpendicularly by impression of such pulse bias voltage. Thereby, even if the resist mask pattern of a sample is very detailed, vertical incidence can perform highly precise etching processing corresponding to a mask pattern.

[0174] In addition, in the plasma etching system of this invention shown below in drawing 1 , the direct current voltage of an electrostatic adsorption circuit and the pulse voltage of a pulse bias-power-supply circuit can be superimposed and generated, and a circuit can also be constituted in common. Moreover, it separates into another electrode, an electrostatic adsorption circuit and a pulse bias-power-supply circuit are prepared, and pulse bias can be prevented from affecting electrostatic adsorption.

[0175] It can replace with the electrostatic adsorption circuit in the example of the plasma etching system shown in drawing 1 , and can also use, other adsorption means, for example, vacuum adsorption means.

[0176] Plasma treatment equipment equipped with the electrostatic adsorption circuit of this invention and pulse bias voltage impression circuit which were described above is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.

[0177] Next, the conventional fault is improved, ion, the amount of radical formation, and quality are controlled by other examples of this invention shown in drawing 37 , and other examples of the plasma

etching system which makes very detailed plasma treatment possible are described.
[0178] That is, the location which performs the first plasma production is set as a location different from a vacuum processing room by the upstream of a vacuum processing room which is installing the sample, the metastable atom generated there is poured into a vacuum processing room, and it is considering as the configuration which generates the second plasma at a vacuum processing room. In addition to the plasma etching system shown in drawing 1 , it has the gas supply section 60 for the sources of an ion radical, and the plasma generating room 62 for metastable atom generating. Moreover, the introductory root connected to the gas supply section for the sources of an ion radical other than the root which introduces the gas containing a metastable atom into a vacuum processing room is established in the up electrode 12.
[0179] The description of this example is as follows.
** High-frequency power is impressed, plasma-ize the gas supplied from the gas supply section 36 for metastable atom generating at the plasma generating room 62 for metastable atom generating, carry out the amount generating of requests of the desired metastable atom beforehand, and make it flow into the processing room 10. The plasma generating room 62 for metastable atom generating sets an indoor pressure as the high pressure of hundreds mTorr(s) - dozens Torr(s) in order to generate a metastable atom efficiently.
[0180] ** Make the gas from the gas supply section 60 for another side and the sources of an ion radical flow into the processing room 10.
[0181] ** Output the RF of comparatively the low power in the power source 16 for plasma generating, and make the processing room 10 generate the plasma. By impregnation of a metastable atom, since the electron of low energy about 5eV or less can also make ion generate efficiently, it is low electron temperature (about 6eV or less, preferably about 4eV or less), and little [sharply] plasma is acquired for a high energy electron about 15eV or more. For this reason, the gas for the sources of a radical can secure a complement and quality, without producing superfluous dissociation. On the other hand, the amount of ion is controllable by the amount of the metastable atom generated at the plasma generating room 62 for metastable atom generating, and the gas for the ion sources from the gas supply section 60 for the sources of an ion radical.
[0182] Thus, since the quality and the amount of ion and radical formation can be controlled, the good engine performance is obtained also in very detailed plasma treatment. The gas (C_2H_4, CH_4, CH_3OH, etc.) which contains C and H in fluorocarbon gas, such as CHF_3, CH_2F_2, C_4F_8, or CF_4, as gas for the sources of a radical if needed is mixed, and it is. As gas for metastable atom generating, what made **-SU one kind or two kinds of rare gas is used. Ion is efficiently generable by using rare gas with the following property etc. as gas for the ion sources.
[0183] At least energy ** of said metastable atom is received, and although the direction like ****** of the thing which has at least low ****** of the gas for the ion sources, or the gas for the ion sources is high, a thing with the small (about 5eV or less) difference is used.
[0184] In addition, although it falls efficiently, it cannot add especially as gas for the ion sources, but the above-mentioned gas for metastable atom generating and the gas for the sources of a radical can also be substituted.
[0185] Next, other examples of this invention which controls the quality and the amount of ion and radical formation to drawing 38 are shown. Although the fundamental idea is the same as drawing 37 , in drawing 37 , its distance between the plasma room 62 for metastable atom generating and the vacuum processing room 10 is long, and it is an example carried out as a cure when attenuation of a metastable atom during this period is large. 41 is a magnetron as a source of an oscillation of microwave, 42 is the waveguide of microwave, it is a quartz plate for 43 carrying out vacuum **** of the first plasma production room 45, and passing microwave, and 44 is a quartz plate for gas distribution. At the first plasma production room 45, the plasma is generated by said microwave in the gas pressure of several 100 mTorr(s) to several 10 Torr(s), and a metastable atom is generated.
[0186] In drawing 38 , since the source location of a metastable atom and distance between vacuum processing rooms can be shortened as compared with drawing 37 , a metastable atom can be poured into a vacuum processing room by the high consistency, and the amount of the ion in the vacuum processing room 10 can be increased. The processing room 10 is maintained at the pressure of 5 - 50mTorr, and by RF generator 16 20MHz or more, 5eV of high density low electron-temperature plasma of 3 is preferably generated cm 11th power a set /from the 10th power of 10 in 3eV or less, and ionization of the gas for the ion sources is advanced, avoiding dissociation of CF_2 which needs 8eV or more as dissociation energy. Consequently, on the front face of a sample 40, the following reaction assisted by the incidence of the ion accelerated by several 100 V by bias power supply 17 mainly advances.

SiO_2+2CF_2 -> In CF_2, since Si or SiN used as furring which are SiF_4 **+2CO ** were not etched, oxide film etching of a high selection ratio of them was attained.
[0187] Moreover, the increment of F according a part to dissociation in CF_2 is decreased with the up electrode covering 30 which consists of silicon, carbon, or SiC.
[0188] As stated in the top, by adjusting the gas for the sources of a radical, and the gas for the ion sources, the ratio of the ion in the processing room 10 and a radical could be controlled almost independently, and it became easy to control the reaction in the front face of a sample 40 to a desired thing.
[0189] Plasma treatment equipment equipped with the electrostatic adsorption circuit and pulse bias voltage impression circuit of this invention is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.
[0190] Next, other examples of this invention which controls ion and a radical independently to drawing 39 are shown. In drawing 39 , the gas (C_2H_4, CH_3OH, etc.) which contains C and H in fluorocarbon gas, such as CHF_3, CH_2F_2, C_4F_8, or CF_4, if needed is mixed, and it puts into the plasma generating room 62 for radical generating via a bulb 70 from the part which drawing 39 A Becomes.
[0191] At the plasma generating room 62 for radical generating, the output of the RF power source (several MHz or several 10MHz) 63 is impressed to a coil 65, the plasma is generated with the gas pressure of several 100 mTorr(s) to several 10 Torr(s), and CF_2 radical is mainly generated. CF_3 and F which are generated in coincidence are decreased by H component.
[0192] In addition, since it is difficult to decrease components, such as CF and O, sharply at the plasma generating room 62 for radical generating, the unnecessary component removal room 65 is formed next. Here, the wall of the quality of the materials (carbon, Si, SiC, etc.) containing carbon or Si is installed, and an unnecessary component is transformed to reduction or another gas with few bad influences. The outlet of the unnecessary component removal room 65 is connected to a bulb 71, and CF_2 supplies the gas presentation of a principal component.
[0193] In addition, since deposits, such as a depository object, are accumulated between [many] a bulb 70 and a bulb 71, they need cleaning and exchange for a short period of time comparatively. For this reason, while making atmospheric-air disconnection and exchange easy, it has connected with an exhauster 74 via a bulb 72 for compaction of the vacuum starting time amount at the time of re-starting. In addition, an exhauster 74 may be used also [exhauster / for the processing rooms 10].
[0194] Moreover, the gas B for the ion sources (rare gas, such as argon gas and xenon gas) is supplied to the aforementioned outlet and aforementioned connector processing room of a bulb 71 via a bulb 73.
[0195] The processing room 10 is maintained at the pressure of 5-40mT, and by RF generator 16 20MHz or more which became irregular, 5eV of high density low electron-temperature plasma of 3 is preferably generated cm 11th power a set /from the 10th power of 10 in 3eV or less, and ionization of the gas for the ion sources is advanced, avoiding dissociation of CF_2 which needs 8eV or more as dissociation energy. Consequently, on the front face of a sample 40, the following reaction assisted by the incidence of the ion accelerated by several 100 V by bias power supply 17 mainly advances.
SiO_2+2CF_2 -> In CF_2, since Si or SiN used as furring which are SiF_4 **+2CO ** were not etched, oxide film etching of a high selection ratio of them was attained.
[0196] Moreover, the increment of F according a part to dissociation in CF_2 is decreased with the up electrode covering 30 which consists of silicon, carbon, or SiC.
[0197] As stated in the top, by adjusting the gas A for the sources of a radical, and the gas B for the ion sources, the ratio of the ion in the processing room 10 and a radical could be controlled almost independently, and it became easy to control the reaction in the front face of a sample 40 to a desired thing. Moreover, since an unnecessary depository component etc. was eliminated at the unnecessary component removal room 65 and he was trying not to carry into the processing room 10 as much as possible, the depository in the processing room 10 was reduced sharply, and the frequency of cleaning where opened the processing room 10 wide to atmospheric air, and it was performed has also reduced it sharply.
[0198] Next, other examples which control ion and a radical independently to drawing 40 are shown. From A, it mixes with ion source gas B via through, the unnecessary component removal room 65, and a bulb 71 in the heating pipe section 66 via a bulb 70, and oxidation hexafluoropropylene gas (it omits CF_3CFOCF_2 and Following HFPO) is sent to the way of the processing room 10. In the heating pipe section 66, HFPO is heated at 800 degrees C - 1000 degrees C, and the following pyrolysis generates CF_2.
CF_3CFOCF_2 -> Although the comparatively stable matter is hard to decompose $CF_2+CF_3CFOCF_3CFO$,

since a part is understood and unnecessary O and F are generated, the unnecessary component removal room 65 was formed after the heating pipe section 66, and the unnecessary component has been changed into the matter out of which removal or a bad influence does not come. A part of CF3CFOCF(s)2 flow into the processing room 10 without decomposing, but with the plasma 5eV or less of low electron temperature, in order not to dissociate, they do not pose a problem.
[0199] In addition, the reaction in how to use a bulb 72 and an exhauster 74 and the processing room 10 is the same as the case of drawing 39 .
[0200] Plasma treatment equipment equipped with the electrostatic adsorption circuit and pulse bias voltage impression circuit of this invention is applicable not only to the etching processing described above but plasma treatment equipments, such as a CVD system, by replacing with etching gas and adding modification of introducing CVD gas.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become one example of this invention.
[Drawing 2] It is in the condition which added the magnetic field which produces electronic cyclotron resonance, and is drawing showing an example of the change of a plasma consistency when changing the frequency of the RF generator which generates the plasma.
[Drawing 3] It is drawing showing the situation of the energy gain k which an electron acquires from RF electric field at the time of cyclotron resonance and no resonating.
[Drawing 4] While grounding the up electrode of a magnetron discharge electrode and giving Field B to a lower electrode, it is drawing showing the relation of variation deltaV of the ion acceleration voltage VDC by which induction is carried out to the magnetic field strength and the sample when impressing high-frequency power, and the induced voltage in a sample.
[Drawing 5] It is the explanatory view of the magnetic influence of the plasma etching system of drawing 1 .

[Drawing 6] It is the explanatory view of the ECR field of the plasma etching system of drawing 1 .
[Drawing 7] It is drawing showing the desirable example of an output wave used in the pulse bias power supply of this invention.
[Drawing 8] Pulse duty ratio: (T1/T0) is T0 while it is fixed. It is drawing showing the potential wave on the front face of a sample at the time of making it change, and the probability distribution of ion energy.
[Drawing 9] While it is fixed, it is a pulse duty ratio T0 It is drawing showing the potential wave on the front face of a sample at the time of making it change, and the probability distribution of ion energy.
[Drawing 10] It is drawing showing the relation of the maximum electrical potential difference VCM in a round term of the electrical potential difference produced between the OFF (T0-T1) period of a pulse, and the both ends of an electrostatic adsorption film.
[Drawing 11] It is drawing showing a pulse duty ratio and the relation of (VDC/vp).
[Drawing 12] It is drawing showing the ion energy dependency of the etching rates ESi and ESiO2 of the silicon when plasma-izing chlorine gas, and an oxide film.
[Drawing 13] ethyne great of the oxide film and silicon when plasma-izing C4F8 gas as an example of etching of an oxide film -- it is drawing showing ion energy distribution of ESiO2 and ESi.
[Drawing 14] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 15] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 16] It is the explanatory view of the magnetic field distribution property of the drawing 15 plasma etching system.
[Drawing 17] It is the explanatory view of the ECR field of the plasma etching system of drawing 15 .
[Drawing 18] It is drawing of longitudinal section of the plasma etching system which becomes other examples of this invention.
[Drawing 19] It is the explanatory view of the magnetic field distribution property of the plasma etching system of drawing 18 .
[Drawing 20] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 21] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.

[Drawing 22] It is the explanatory view of the magnetic field distribution property of the plasma etching system of drawing 21 .
[Drawing 23] It is the important section cross-sectional view of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 24] It is drawing of longitudinal section of the plasma etching system of drawing 23 .
[Drawing 25] It is drawing showing other examples of magnetic field means forming.
[Drawing 26] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 27] It is drawing of longitudinal section of the plasma etching system of 2 electrode molds which become other examples of this invention.
[Drawing 28] It is drawing of longitudinal section of 2 electrode mold plasma etching system which becomes other examples of this invention.
[Drawing 29] It is the explanatory view of the magnetic field distribution property of the plasma etching system of drawing 28 .
[Drawing 30] It is drawing of longitudinal section of 2 electrode mold plasma etching system which becomes other examples of this invention.
[Drawing 31] It is drawing of longitudinal section of other examples which improved 2 electrode mold plasma etching system shown in drawing 1 .
[Drawing 32] It is drawing showing the frequency of the power source for plasma generating, and the relation of the stable discharge minimum gas pressure.
[Drawing 33] It is drawing having shown the frequency of pulse bias power supply, and the relation of accumulation power.
[Drawing 34] It is drawing of longitudinal section of the example which is an inductive-coupling mold discharge method among external energy supply discharge methods, and applied this invention to the non-magnetic field type plasma etching system.
[Drawing 35] It is drawing of longitudinal section of a plasma etching system which becomes other examples of this invention.
[Drawing 36] It is the front view which carried out the longitudinal section of some equipments which applied this invention to microwave plasma treatment equipment.
[Drawing 37] It is drawing of longitudinal section of a plasma etching system which becomes other examples of this invention.
[Drawing 38] It is the front view which becomes other examples of this invention and which carried out the longitudinal section of some plasma treatment equipments.
[Drawing 39] It is controllable drawing of longitudinal section of 2 electrode plasma etching system independently about the ion and radical which become other examples of this invention.
[Drawing 40] It is the controllable partial detail drawing of 2 electrode plasma etching system independently about the ion and radical which become other examples of this invention.
[Description of Notations]
10 -- a processing room, a 12 -- up electrode, a 15 -- lower electrode, and 16 -- an RF generator, 17 -- pulse bias power supply, 18 -- vacuum pump, and 20 -- an electrostatic chuck, a 22 -- electrostatic adsorption film, 23 -- DC power supply, and 30 -- up electrode covering, 32 -- gaseous diffusion plate 32, and 36 -- the gas supply section 3, 40 -- sample, the source of a 161 -- RF generator modulating signal, and 200 -- the magnetic field means forming 200, a 201 -- core, and 202 -- -- electromagnetism -- a coil and 203 -- insulators

---

[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) **公開特許公報**（Ａ）　(11)特許出願公開番号

特開平10－261498

(43)公開日　平成10年(1998) 9 月29日

(51)Int.Cl.⁶	識別記号	ＦＩ	
Ｈ０５Ｈ　1/46		Ｈ０５Ｈ　1/46	Ｃ
			Ｌ
Ｃ２３Ｃ　16/50		Ｃ２３Ｃ　16/50	
Ｃ２３Ｆ　4/00		Ｃ２３Ｆ　4/00	Ｇ
			Ａ

審査請求　未請求　請求項の数31　ＯＬ　（全 32 頁）　最終頁に続く

(21)出願番号　特願平9－45275

(22)出願日　平成９年(1997) ２月28日

(31)優先権主張番号　特願平8－44391

(32)優先日　平８(1996) ３月１日

(33)優先権主張国　日本（ＪＰ）

(31)優先権主張番号　特願平9－7938

(32)優先日　平９(1997) １月20日

(33)優先権主張国　日本（ＪＰ）

(71)出願人　000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地

(72)発明者　加治　哲徳
山口県下松市大字東豊井794番地　株式会社日立製作所笠戸工場内

(72)発明者　渡辺　克哉
山口県下松市大字東豊井794番地　株式会社日立製作所笠戸工場内

(72)発明者　三谷　克彦
山口県下松市大字東豊井794番地　株式会社日立製作所笠戸工場内

(74)代理人　弁理士　高田　幸彦　（外１名）

最終頁に続く

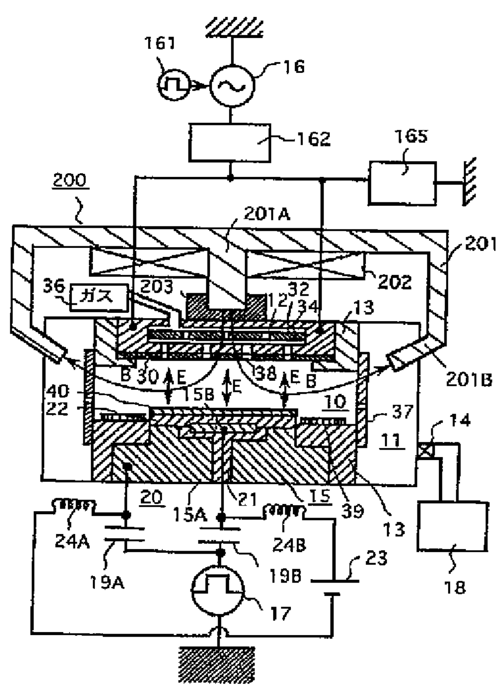
(54)【発明の名称】　プラズマ処理装置及びプラズマ処理方法

(57)【要約】

【課題】大口径の試料について微細パターンの精密な加工が容易で、また、微細加工時の選択比も向上させたプラズマ処理装置及びプラズマ処理方法を提供する。

【解決手段】真空処理室１０と、この真空処理室内で処理される試料４０を配置するための試料台１５と、高周波電源１６を含むプラズマ生成手段とを有するプラズマ処理装置であって、一対の電極間１２，１５には、５０ないし２００ＭＨｚのＶＨＦ帯電源を印加する高周波電源と、前記高周波電源により前記一対の電極間に生ずる電界と交差する方向に、１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場を形成する磁場形成手段とを備え、前記磁場の前記下部電極に沿う方向の成分の最大となる部分が、前記上部電極面上もしくは両電極の中央よりも上部電極側になるように前記磁場形成手段を設定し、前記磁場と前記電界との相互作用により、前記一対の電極間に電子のサイクロトロン共鳴領域を形成する。

図１



【特許請求の範囲】

【請求項１】真空処理室と、一対の電極を含むプラズマ生成手段と、該真空処理室内で処理される試料を載置する試料載置面を有する試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置において、

前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯の高周波電力を印加する高周波電源と、

前記高周波電源により前記一対の電極間もしくはその近辺に生ずる電界と交差する方向に、静磁場もしくは低周波磁場を形成する磁場形成手段とを備え、

前記一対の電極間に、前記磁場と前記電界との相互作用による電子のサイクロトロン共鳴領域を形成することを特徴とするプラズマ処理装置。

【請求項２】真空処理室と、一対の電極を含むプラズマ生成手段と、前記電極の一方を兼ねると共に該真空処理室内で処理される試料を載置する試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置において、

前記一対の電極間に、５０ＭＨｚないし２００ＭＨｚのＶＨＦ帯電力を印加する高周波電源と、

前記高周波電源により前記一対の電極間もしくはその近辺に生ずる電界と交差する方向に、１７ガウス以上７２ガウス以下の静磁場もしくは低周波磁場の部分を形成する磁場形成手段とを備え、

前記磁場の前記試料台の面に沿う方向の成分の最大となる部分が、前記一対の電極の中央よりも前記試料台と反対側になるように前記磁場形成手段を設定し、

前記一対の電極間に、前記磁場と前記電界との相互作用による電子のサイクロトロン共鳴領域を形成することを特徴とするプラズマ処理装置。

【請求項３】請求項１または２において、前記磁場形成手段により形成される磁場の強度を、前記試料面上で該面に平行な磁場成分が３０ガウス以下となるようにしたことを特徴とするプラズマ処理装置。

【請求項４】真空処理室と、一対の電極を含むプラズマ生成手段と、前記電極の一方を兼ねると共に該真空処理室内で処理される試料を配置するための試料台とを有するプラズマ処理装置において、

前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯電力を印加する高周波電源と、

前記電極が、前記高周波電源に接続された第１の電極と、前記試料台を兼ねると共にイオンエネルギー制御用のバイアス電源に接続された第２の電極により構成され、該一対の電極間の距離が３０ないし１００mmであり、

前記真空処理室を０．４Ｐａないし４Ｐａに減圧する減圧手段と、

前記一対の電極間もしくはその近辺の電界と交差する方向に、１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場の部分を形成する磁場形成手段とを備え、

前記第１の電極面上もしくは両電極の中央よりも前記第１の電極側に、前記磁場と前記高周波電源による電界との相互作用による電子のサイクロトロン共鳴領域を形成することを特徴とするプラズマ処理装置。

【請求項５】請求項１、２または４のいずれかにおいて、前記電子のサイクロトロン共鳴効果が前記試料の中央に比べて該試料の周辺部ないしはその外側で大きくなるように、前記磁場形成手段によって形成される前記磁界の密度または方向を調節し、前記試料載置面の全面に対応する位置でプラズマ密度が均一になるように構成したことを特徴とするプラズマ処理装置。

【請求項６】請求項４において、前記磁場形成手段が、前記試料面の中心に対して偏心して回転することにより前記磁場を変更し前記試料に対する前記サイクロトロン共鳴領域の距離を連続的に変更するコアを含むことを特徴とするプラズマ処理装置。

【請求項７】真空処理室と、一対の電極を含むプラズマ生成手段と、該真空処理室内で処理される試料を載置する試料載置面を有する試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置において、

前記電極が、高周波電源に接続された第１の電極と、前記試料台を兼ねる第２の電極と、前記第１の電極の周辺外側に位置し接地された前記処理室の壁部分により構成され、

前記高周波電源が、前記一対の電極間及び前記第１の電極と前記処理室の壁部分間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯の高周波電力を印加する電源であり、

前記処理室の中心付近では互いに打消合い、前記処理室の周辺およ外側では互いに重畳する方向に、１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場の部分を形成する磁場形成手段とを備え、

前記試料載置面の周辺部ないしはその外側付近に、前記磁場と前記高周波電源による電界との相互作用による電子のサイクロトロン共鳴領域を形成することを特徴とするプラズマ処理装置。

【請求項８】請求項７において、前記磁場形成手段が、前記試料の中央付近では互いに磁束を打消し、該試料の周辺部ないしはその外側では互いに磁束を重畳させるように前記処理室の周囲に配置された複数のコイルを備えていることを特徴とするプラズマ処理装置。

【請求項９】請求項４において、前記イオンエネルギー制御用のバイアス電源として、周期が０．２～５μｓで正方向パルス部分のｄｕｔｙが０．４以下のパルスバイアスを容量素子を介して前記試料に加えることを特徴とするプラズマ処理装置。

【請求項１０】請求項１、２または４のいずれかにおいて、

前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、

前記試料台に接続され、該試料台にパルスバイアス電圧

を印加するパルスバイアス印加手段と、
前記パルスバイアス電圧の印加に伴い前記静電吸着手段の静電吸着容量に対応して発生する電圧の上昇を抑制する、電圧抑制手段とを設けたことを特徴とするプラズマ処理装置。
【請求項１１】請求項１０において、前記電圧抑制手段は、パルスの一周期中の前記静電吸着手段の静電吸着膜による電圧変化を、前記パルスバイアス電圧の１／２以下に抑制するように構成されていることを特徴とするプラズマ処理装置。
【請求項１２】真空処理室と、一対の電極を含むプラズマ生成手段と、前記電極の一方を兼ねると共に該真空処理室内で処理される試料を配置するための試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置による試料のプラズマ処理方法において、
減圧手段により前記真空処理室内を減圧するステップと、
磁場形成手段により、前記一対の電極間の電界と交差する方向に１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場の部分を形成するステップと、
高周波電源により前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯電力を印加して、前記一対の電極の間に、前記磁場と前記高周波電源による電界との相互作用による電子のサイクロトロン共鳴領域を形成するステップと、
前記電子のサイクロトロン共鳴により生成されるプラズマにより、前記試料を処理するステップとを有することを特徴とするプラズマ処理方法。
【請求項１３】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、一対の電極を含むプラズマ生成手段とを有するプラズマ処理装置による試料のプラズマ処理方法において、
前記電極が、前記高周波電源に接続された第１の電極と、前記試料台を兼ねると共にイオンエネルギー制御用のバイアス電源に接続された第２の電極とからなる一対の電極により構成され、該一対の電極間の距離が３０ないし１００mmであり、
減圧手段により前記真空処理室内を０．４Ｐａないし４Ｐａに減圧するステップと、
磁場形成手段により、前記一対の電極間の電界と交差する方向に１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場の部分を形成するステップと、
高周波電源により前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯電力を印加して、前記一対の電極の間に、前記磁場と前記高周波電源による電界との相互作用による電子のサイクロトロン共鳴領域を形成するステップと、
前記電子のサイクロトロン共鳴により生成されるプラズマにより、前記試料を処理するステップとを有することを特徴とするプラズマ処理方法。
【請求項１４】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、高周波電源を含むプラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記試料にパルスバイアス電圧を印加するパルスバイアス印加手段とを備え、
前記高周波電源として１０MHｚ～５００MHｚの高周波電圧を印加するとともに、前記真空処理室を０．５～４．０Ｐａに減圧するように構成されていることを特徴とするプラズマ処理装置。
【請求項１５】一方の電極に試料が配置される一対の対向する電極と、
前記試料が配置される雰囲気に、エッチングガスを導入するガス導入手段と、
前記雰囲気を０．５～４．０Ｐａに減圧排気する排気手段と、
前記一対の対向電極に１０MHｚ～５００MHｚの高周波電圧を印加する高周波電源と、
前記圧力下で前記エッチングガスをプラズマ化するプラズマ生成手段と、
前記試料のエッチング時に前記一方の電極に、パルスバイアス電圧を印加するパルスバイアス印加手段からなり、
前記試料中の絶縁膜をプラズマ処理することを特徴とするプラズマ処理装置。
【請求項１６】真空処理室と、該真空処理室で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記試料台に接続され、該試料台にパルスバイアス電圧を印加するパルスバイアス印加手段と、
前記パルスバイアス電圧の印加に伴い前記静電吸着手段の静電吸着容量に対応して発生する電圧の上昇を抑制する、電圧抑制手段とを設け、
該電圧抑制手段は、パルスの一周期中の前記静電吸着手段の静電吸着膜による電圧変化を、前記パルスバイアス電圧の１／２以下に抑制するように構成されていることを特徴とするプラズマ処理装置。
【請求項１７】間隙が１０mm～５０mmの一対の対向する電極と、
一方の前記電極に試料を静電吸着力によって保持する静電吸着手段と、
前記試料が保持された雰囲気に、エッチングガスを導入するガス導入手段と、
前記雰囲気を０．５～４．０Ｐａに減圧排気する排気手段と、
前記圧力下で前記エッチングガスを１０MHｚ～５００MH

ｚの高周波電力によりプラズマ化するプラズマ生成手段と、
前記試料が配置された前記一方の電極にパルスバイアス電圧を印加するパルスバイアス印加手段からなり、
前記試料中の絶縁膜をプラズマ処理することを特徴とするプラズマ処理装置。
【請求項１８】請求項１６または１７のいずれかに記載のプラズマ処理装置において、
前記パルスバイアス電圧の印加に伴い前記静電吸着手段の静電吸着容量に対応して発生する電圧の上昇を抑制する、電圧抑制手段を設け、
前記電圧抑制手段として、パルスの一周期中の前記静電吸着手段の静電吸着膜による電圧変化が、前記パルスバイアス電圧の１／２以下になるように、前記パルスバイアス電圧の周期を設定したことを特徴とするプラズマ処理装置。
【請求項１９】真空処理室に設けられた電極の一方に試料を配置するステップと、
該試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置された雰囲気に、処理ガスを導入するステップと、
前記雰囲気を前記試料の処理圧力に減圧排気するステップと、
前記圧力下で前記処理ガスをプラズマ化するステップと、
該試料を前記プラズマにより処理するステップと、
前記試料にパルスバイアス電圧を印加するステップと、からなることを特徴とするプラズマ処理方法。
【請求項２０】間隙が１０mm～５０mmの一対の対向する電極の一方に、試料を配置するステップと、
該配置された試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置された雰囲気に、エッチングガスを導入するステップと、
前記雰囲気を０．５～４．０Ｐａに減圧するステップと、
１０MHｚ～５００MHｚの高周波電力を印加し、前記圧力下で前記エッチングガスをプラズマ化するステップと、
該プラズマにより前記試料をエッチングするステップと、
該エッチング時に前記一方の電極に、パルスバイアス電圧を印加するステップからなり、
前記試料中の絶縁膜をプラズマ処理することを特徴とするプラズマ処理方法。
【請求項２１】真空処理室に設けられた電極の一方に試料を配置するステップと、
該試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置された雰囲気に、エッチングガスを導入するステップと、
前記雰囲気を減圧排気するステップと、
前記減圧下でエッチングガスをプラズマ化するステップと、
該試料を前記プラズマによりエッチングするステップと、
前記試料にパルスバイアス電圧を印加するステップからなり、
前記パルスバイアス電圧印加時における、パルスの一周期中の前記静電吸着手段の静電吸着膜による電圧変化を、前記パルスバイアス電圧の１／２以下に抑制することを特徴とするプラズマ処理方法。
【請求項２２】対向する電極の一方の電極に試料を配置するステップと、
該配置された試料を静電吸着力によって前記電極に保持するするステップと、
前記試料が配置された雰囲気に、エッチングガスを導入するステップと、
該導入されたエッチングガスをプラズマ化するステップと、
該プラズマにより前記試料をエッチングするステップと、
該エッチング時に前記一方の電極に、２５０Ｖ～１０００Ｖのパルス振幅と０．０５～０．４のデューティ比を有するパルスバイアス電圧を印加するステップからなり、前記試料中の絶縁膜をプラズマ処理することを特徴とするプラズマ処理方法。
【請求項２３】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記試料にバイアス電圧を印加するバイアス印加手段と、
前記真空処理室に、ラジカル発生用ガスを予め分解する手段を有し所望量のラジカルを供給するラジカル供給手段と、
前記真空処理室にイオン発生用ガスを供給する手段と、
前記真空処理室にプラズマを発生させるプラズマ生成手段とを具備し、
前記試料としてSiO_2を用いることを特徴とするプラズマ処理装置。
【請求項２４】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記試料にパルスバイアス電圧を印加するパルスバイアス印加手段と、
前記真空処理室に、ラジカル発生用ガスを予めプラズマ

化し所望量のラジカルを供給するラジカル発生用プラズマ供給手段と、
前記真空処理室に、イオン発生用ガスを供給しプラズマを発生させる前記プラズマ生成手段とを具備し、
前記試料としてSiO_2を用いることを特徴とするプラズマ処理装置。
【請求項２５】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、
高周波電源を含むプラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記試料にパルスバイアス電圧を印加するパルスバイアス印加手段と、
前記真空処理室に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するラジカル発生用プラズマ供給手段と、
前記真空処理室に、イオン発生用ガスを供給しプラズマを発生させる前記プラズマ生成手段とを備え、
前記高周波電源により１０MHz～５００MHzの高周波電圧を印加するとともに、前記真空処理室を０．５～４．０Ｐａに減圧するように構成されていることを特徴とするプラズマ処理装置。
【請求項２６】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、
前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記真空処理室に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するラジカル発生用プラズマ供給手段と、
前記真空処理室に、イオン発生用ガスを供給しプラズマを発生させる前記プラズマ生成手段と、
前記試料台に接続され、該試料台にパルスバイアス電圧を印加するパルスバイアス印加手段と、
前記パルスバイアス電圧の印加に伴い前記静電吸着手段の静電吸着容量に対応して発生する電圧の上昇を抑制する、電圧抑制手段とを具備したことを特徴とするプラズマ処理装置。
【請求項２７】真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、
前記試料台に設けられた静電吸着膜を含み、前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、
前記真空処理室に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するラジカル発生用プラズマ供給手段と、
前記真空処理室に、イオン発生用ガスを供給しプラズマを発生させる前記プラズマ生成手段と、
前記試料台に接続され、該試料台にパルスバイアス電圧を印加するパルスバイアス印加手段と、
前記パルスバイアス電圧の印加に伴い前記静電吸着膜の両端間に生ずる電圧を抑制する、電圧抑制手段とを具備し、
該電圧抑制手段は、前記静電吸着手段の静電吸着膜による電圧を、前記パルスバイアス電圧の１／２以下に抑制することを特徴とするプラズマ処理装置。
【請求項２８】対向する一方の電極に試料を配置するステップと、
該配置された試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置・保持された雰囲気に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するステップと、
前記雰囲気に、イオン発生用ガスを供給するステップと、
前記雰囲気を、０．５～４．０Ｐａに減圧排気するステップと、
前記対向する電極に１０MHz～５００MHzの高周波電圧を印加し、前記圧力下で供給されたイオン発生用ガスをプラズマ化するステップと、
該プラズマにより前記試料をエッチング処理するステップと、
該エッチング処理時に前記一方の電極に、パルスバイアス電圧を印加するステップからなり、
前記試料としてSiO_2を用いることを特徴とするプラズマ処理方法。
【請求項２９】真空処理室に設けられた電極の一方に試料を配置するステップと、
該試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置・保持された雰囲気に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するステップと、
前記雰囲気に、イオン発生用ガスを供給するステップと、
前記雰囲気に３０MHz～１００MHzの高周波電圧を印加し、前記圧力下で供給されたイオン発生用ガスをプラズマ化するステップと、
該試料を前記プラズマにより処理するステップと、
前記試料にパルスバイアス電圧を印加するステップからなり、
前記試料としてSiO_2を用いることを特徴とするプラズマ処理方法。
【請求項３０】真空処理室に設けられた電極の一方に試料を配置するステップと、
該試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置・保持された雰囲気に、ラジカル発生用

ガスを予めプラズマ化し所望量のラジカルを供給するステップと、
前記雰囲気に、イオン発生用ガスを供給するステップと、
前記雰囲気を、前記試料の処理圧力に減圧排気するステップと、
前記圧力下で供給されたイオン発生用ガスをプラズマ化するステップと、
該試料を前記プラズマにより処理するステップと、
前記試料にパルスバイアス電圧を印加するステップからなり、
前記静電吸着手段の電圧が、前記パルスバイアス電圧の１／２以下となるようにしたことを特徴とするプラズマ処理方法。

【請求項３１】真空処理室に設けられた対向する電極の一方に試料を配置するステップと、
該試料を静電吸着力によって前記電極に保持するステップと、
前記試料が配置・保持された雰囲気に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するステップと、
前記雰囲気に、イオン発生用ガスを供給するステップと、
前記雰囲気を、０．５～４．０Ｐａに減圧排気するステップと、
前記対向する電極間に３０MHz～１００MHzの高周波電圧を印加し、前記圧力下で供給されたイオン発生用ガスをプラズマ化するステップと、
該試料を前記プラズマにより処理するステップと、
前記試料にパルスバイアス電圧を印加するステップからなることを特徴とするプラズマ処理方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明はプラズマ処理装置および処理方法に係り、特に半導体製造工程における微細なパターンを形成するのに好適なプラズマ処理装置およびプラズマ処理方法に関する。

【０００２】

【従来の技術】プラズマ処理は、半導体デバイスの高集積化に伴ってますます微細加工性や処理速度の向上が要求されて来ている。この要求に応えるためには、処理ガス圧の低圧化，プラズマの高密度化が必要になって来ている。

【０００３】処理ガス圧の低圧化，高密度化を目指すものとして、(1) マイクロ波(2.45ＧＨｚ)電磁界と静磁場（８７５Ｇ）とのサイクロトロン共鳴現象（ＥＣＲと略す）を利用したもの、（２）ＲＦ周波数の電源によりコイルを励振し、誘導電磁界を発生させて、プラズマを発生させるもの（ＩＣＰと略す）などがある。

【０００４】ところで、フルオロカーボン系ガスを用いて、酸化膜系の膜をエッチングする場合、上記（1)に示したＥＣＲや（２）に示したＩＣＰ方式では、ガスの解離が進みすぎ、酸化膜系膜の下地（ＳｉやＳｉＮ）に対する選択比を高くすることが困難であるのが現状である。

【０００５】一方、平行平板間にＲＦ周波数の電圧を印加し、プラズマを発生させる従来の方法は、１０Ｐａ以下の圧力で安定に放電させることは困難である。この対策として、（３）特開平７－２９７１７５号公報や特開平３－２０４９２５号公報に示されたような、数十ＭＨｚ以上の高い周波数の電圧によりプラズマを生成させ数ＭＨｚ以下の低い周波数で試料のバイアス制御を行う２周波励起法や、（４）特開平２－３１２２３１号公報に示されたような、試料表面に誘起された自己バイアス電界（Ｅ）と交差する方向に磁界Ｂを加え、電子のローレンツ力による電子の閉じ込め作用を利用したマグネトロンＲＩＥ（Ｍ－ＲＩＥと略す）法がある。

【０００６】また、低ガス圧下においてプラズマ密度を増加させる方法として、特開昭５６－１３４８０号公報に記載されたものがある。これは、電磁波であるマイクロ波（２．４５ＧＨｚ）と静磁場（８７５Ｇａｕｓｓ）とによる電子サイクロトロン共鳴（ＥＣＲ）を活用し、０．１～１Ｐａの低ガス圧でも高いプラズマ密度が得られるようにしたものである。

【０００７】一方、プラズマを用いて半導体のエッチング処理や成膜処理等を行う技術分野において、被処理物（例えば半導体ウェハ基板、以下試料と略する。）を配置する試料台に対して、プラズマ中のイオンを加速するための高周波電源と、静電吸着力によって試料を試料台に保持させる静電吸着膜とを備えた処理装置が採用されている。

【０００８】例えば、ＵＳＰ５，３２０，９８２号明細書に記載された装置は、マイクロ波でプラズマを発生させ、静電吸着力によって試料を試料台に保持させると共に試料と試料台との間に伝熱ガスを介在させて試料の温度制御を行いながら、正弦波出力の高周波電源をバイアス電源として、該電源を試料台に接続して試料に入射するイオンエネルギーを制御するものである。

【０００９】また、特開昭６２－２８０３７８号公報では、プラズマ－電極間の電界強度を一定化するパルス状のイオン制御バイアス波形を発生させ試料台に印加することにより、試料に入射するイオンエネルギーの分布幅を狭くでき、エッチングの加工寸法精度や被処理膜と下地材とのエッチング速度比を数倍に上げることが可能となることが記載されている。

【００１０】また、特開平６－６１１８２号公報では、電子サイクロトロン共鳴を利用してプラズマを発生させ、試料に、パルスデューティが０．１％程度以上の幅のパルスバイアスを印加し、ノッチの発生を防止することが記載されている。

【００１１】なお、ＶＨＦ帯電磁波と静磁場とによりサイクロトロン共鳴を起こし、プラズマ密度を向上させる例として、Ｊａｐ．Ｊ．Ａｐｐｌ．ｐｈｙｓ，Vol.28, No.10, October, 1989, PP. L 1860- L 1862に記載のものがある。しかし、本例で同軸形状の中心導体に１４４MHzの高周波を印加し、中心導体に平行な５１Ｇの磁場を加え、サイクロトロン共鳴を生じさせて、高密度のプラズを発生させ、このプラズマ発生部の下流にアースされた試料台を設置している。

【００１２】

【発明が解決しようとする課題】上記従来技術中、特開平７－２８８１９５号公報や特開平７－２９７１７５号公報に記載のプラズマ発生方式は、１３．５６ＭＨｚや数十ＭＨｚの高周波によりプラズマを発生させるものである。数十～５Ｐａ（パスカル）程度のガス圧では、酸化膜のエッチングに良好なプラズマを発生させることができる。しかし、０．２μm程度以下のパターン寸法の微細化にともない、処理形状の垂直化がより強く要求されるようになってきており、このためには、ガス圧の低下が必須になって来ている。

【００１３】しかし、上記した２周波励起法やＭ－ＲＩＥ法では、４Ｐａ以下（０．４～４Ｐａ）で5×10^{10} cm^{-3}程度以上の所望の密度のプラズマを安定に生成させることが困難である。例えば、上記２周波励起法では、プラズマ励起周波数を高くしていっても、５０ＭＨｚ程度以上ではプラズマ密度があまり増加しないか、逆に低下する減少が出てきて、０．４～４Ｐａの低ガス圧でプラズマ密度を5×10^{10} cm^{-3}以上にすることは困難である。

【００１４】また、Ｍ－ＲＩＥ法では、試料表面に生ずる電子のローレンツ力による電子の閉じ込め作用により生成されるプラズマ密度は、試料全面で均一でなければならない。しかし、Ｅ×Ｂのドリフトにより、一般にプラズマ密度に面内の片寄りが生じる欠点がある。試料表面に直接、電子の閉じ込め作用で形成されるプラズマ密度の片寄りは、電界強度の強い試料近傍のシース付近で発生するため、拡散等の方法によって補正することはできない。

【００１５】この解決法として特開平７－２８８１９５号公報に記載されている様に、Ｅ×Ｂによる電子のドリフト方向に磁界強度が弱くなる様に磁石を配置することにより、試料に平行な磁場の最大値として２００ガウスを加えても、偏りの無い均一なプラズマガ得られる。しかし、磁界強度分布を一度固定すると、プラズマが均一となる条件がある特定の狭い範囲に限定されるため、処理条件の変化には容易に追随できない欠点がある。特に、φ３００以上の大口径試料に対し、電極間の距離が２０mm程度以下で狭い場合、試料端部上の圧力より試料中央部上の圧力が１割以上高くなり、試料上の圧力差を避けるため試料台と対向電極間の間隔を３０mm以上に設定する場合、困難性が特に増す傾向にある。

【００１６】このように、上記した２周波励起法やＭ－ＲＩＥ法では、０．４－４Ｐａの低圧で、5×10^{10} cm^{-3}のプラズマ密度をφ３００mmの試料面内で均一にすることは困難である。従って、２周波励起法やＭ－ＲＩＥ法では、φ３００mm以上の大口径のウェハに対し、均一でかつ高速加工性を有して０．２ミクロン径以下の加工を、下地（ＳｉやＳｉＮ等）との選択比を高く加工することは困難な状況である。

【００１７】一方、低ガス圧によるプラズマ密度を大幅に増加させる方法として、上記従来技術中の特開昭５６－１３４８０号公報に記載されたものがある。しかし、この方式では、ガスの解離が進みすぎ、フッ素と炭素とを含有するガスを用いてシリコン酸化膜や窒化膜等をエッチングした場合、フッ素原子／分子やフッ素イオンが多量に発生し、所望の下地（Ｓｉ等）との選択比が得られないという欠点があった。ＲＦ電力の誘導電磁界を用いるＩＣＰ法も上記ＥＣＲ法と同様に解離が進みすぎる欠点があった。

【００１８】また、処理ガスを試料の周辺から排気する構成が一般に取られており、この場合、試料中央部の密度が高く、試料周辺部のプラズマ密度が低くなる傾向となり、試料全面での処理の均一性がそこなわれる欠点があった。この欠点を改善するため試料の周辺付近に環状の土手（フォーカスリング）を設け、ガス流を澱ませることが行われているが、この土手に反応生成物が付着し、異物発生源となり歩留まりが低下する欠点を持っていた。

【００１９】一方、試料に入射するイオンのエネルギー制御するため、試料を載置する電極に正弦波のＲＦバイアスを加えることが行われている。その周波数として数１００ＫＨｚ～１３．５６ＭＨｚが用いられているが、この周波数帯では、シース内の電界の変化にイオンが追随するため入射するイオンのエネルギー分布が、低いエネルギー側と高いエネルギー側との２つでピークを持つダブルピーク型となっていた。高いエネルギー側のイオンは、処理速度は高いが、試料にダメージを与え、低いエネルギー側のイオンは処理速度が低い欠点があり、ダメージをなくそうとすると処理速度が低下し、処理速度を上げようとするとダメージが問題となる欠点があった。一方、ＲＦバイアス周波数を例えば５０ＭＨｚ程度以上の高い値とすると、入射するエネルギー分布はそろってシングルピークに近づくが、プラズマ生成にそのエネルギーの大半が使われ、シースに加わる電圧が大幅に低下するため、入射イオンのエネルギーを単独に制御することが困難になる欠点があった。

【００２０】また、上記従来技術中、特開昭６２－２８０３７８号公報や特開平６－６１１８２号公報に記載のパルスバイアス電源方式は、試料台電極と試料との間に静電吸着用誘電体層を使用して試料にパルスバイアスを

印加する場合の検討がなされておらず、静電吸着方式にそのまま適用するとイオン電流の流入に伴い静電吸着膜の両端間に発生する電圧の増加によりプラズマと試料表面間に印加されるイオン加速電圧が低下し、イオンエネルギー分布が広がるため、試料に十分な温度制御を行いながら、必要とする微細パターンの処理に対処することができない欠点があった。

【００２１】また、ＵＳＰ５，３２０，９８２号明細書に記載された従来の正弦波出力バイアス電源方式では、周波数が高くなると、シース部のインピーダンスがプラズマ自身のインピーダンスに近づくか、それ以下になるため、バイアス電源により試料近傍のシース付近で不要なプラズマが生じ、イオンの加速に有効に使われなくなるとともにプラズマ分布も悪化し、バイアス電源によるイオンエネルギーの制御性が失われる欠点があった。

【００２２】さらにまた、プラズマ処理においては、イオン量、ラジカル量及びラジカル種を適正に制御することが、性能向上のために重要であるが、従来はイオン源やラジカル源となるガスを処理室に流入させ、処理室内でプラズマを発生させて、イオンとラジカルを同時に発生させていたため、試料の処理が微細化するにつれ、その制御の限度が明白となりつつある。

【００２３】また、先に述べたＪａｐ．Ｊ．Ａｐｐｌ．ｐｈｙｓ，２８，１０のＶＨＦ帯のサイクロトロン共鳴を利用した例では、試料台に印加するバイアス電源の設置バイアス電圧を試料面全面にわたって均一に加えるための手段等述べられていない。また、処理室の高さは２００mm程度以上となっており、対向電極での表面反応有効に活用する構成とはなっておらず、この構成で高い選択比を得ることは困難である。

【００２４】本発明の目的は、過度にガスの解離を進めずφ３００mm以上の大口径で均一なプラズマを得ることにより、大口径の試料に対する微細パターンの精密な加工が容易なプラズマ処理装置及びプラズマ処理方法を提供することにある。

【００２５】本発明の他の目的は、大口径の試料の全面にわたって均一かつ高速な処理、特に酸化膜処理を施すことができるプラズマ処理装置およびその処理方法を提供することにある。

【００２６】本発明の他の目的は、試料中の絶縁膜（例えばＳｉO2，ＳｉＮ，ＢＰＳＧ等）に対するプラズマ処理の選択比を向上させたプラズマ処理装置及びプラズマ処理方法を提供することにある。

【００２７】本発明の他の目的は、狭いイオンエネルギー分布を得て安定して低ダメージで制御性良くプラズマ処理の選択比を向上できるプラズマ処理装置及びプラズマ処理方法を提供することにある。

【００２８】本発明の他の目的は、試料の静電吸着により温度制御性を改善し、必要とする微細パターンの処理を精度良く安定して行うプラズマ処理装置及びプラズマ処理方法を提供することにある。

【００２９】本発明の他の目的は、イオンとラジカルを独立に制御することが可能なプラズマ処理装置及びプラズマ処理方法を提供することにある。

【００３０】

【課題を解決するための手段】本発明の特徴は、真空処理室と、一対の電極を含むプラズマ生成手段と、該真空処理室内で処理される試料を載置する試料載置面を有する試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置において、前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯の高周波電力を印加する高周波電源と、前記高周波電源により前記一対の電極間もしくはその近辺に生ずる電界と交差する方向に、静磁場もしくは低周波磁場を形成する磁場形成手段とを備え、前記一対の電極間に、前記磁場と前記電界との相互作用による電子のサイクロトロン共鳴領域を形成することにある。

【００３１】本発明の他の特徴は、真空処理室と、一対の電極を含むプラズマ生成手段と、前記電極の一方を兼ねると共に該真空処理室内で処理される試料を載置する試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置において、前記一対の電極間に、５０ＭＨｚないし２００ＭＨｚのＶＨＦ帯電力を印加する高周波電源と、前記高周波電源により前記一対の電極間もしくはその近辺に生ずる電界と交差する方向に、１７ガウス以上７２ガウス以下の静磁場もしくは低周波磁場の部分を形成する磁場形成手段とを備え、前記磁場の前記試料台の面に沿う方向の成分の最大となる部分が、前記一対の電極の中央よりも前記試料台と反対側になるように設定し、前記一対の電極間に前記磁場と前記電界との相互作用による電子のサイクロトロン共鳴領域を形成することにある。

【００３２】本発明の他の特徴は、真空処理室と、一対の電極を含むプラズマ生成手段と、前記電極の一方を兼ねると共に該真空処理室内で処理される試料を配置するための試料台と、前記真空処理室を減圧する減圧手段とを有するプラズマ処理装置による試料のプラズマ処理方法において、減圧手段により前記真空処理室内を減圧するステップと、磁場形成手段により、前記一対の電極間の電界と交差する方向に、１０ガウス以上１１０ガウス以下の静磁場もしくは低周波磁場の部分を形成するステップと、高周波電源により前記一対の電極間に、３０ＭＨｚないし３００ＭＨｚのＶＨＦ帯電力を印加して、前記一対の電極の間に、前記磁場と前記高周波電源による電界との相互作用による電子のサイクロトロン共鳴領域を形成するステップと、前記電子のサイクロトロン共鳴により生成されるプラズマにより、前記試料を処理するステップとを有することにある。

【００３３】本発明によれば、過度にガスの解離を進めず、φ３００mm以上の大口径で飽和イオン電流分布が±

５％以下の均一なプラズマを得るために、プラズマ生成用高周波電源として、３０ＭＨｚないし３００ＭＨｚ，好ましくは５０ＭＨｚないし２００ＭＨｚのＶＨＦを用いる。一方、前記高周波電源により一対の電極間に生ずる電界と交差する方向に、静磁場もしくは低周波磁場を形成する。これにより、一対の電極間には、試料台の試料載置面に沿って該一対の電極の中央よりも試料台とは反対側に、磁場と電界との相互作用による電子のサイクロトロン共鳴領域が形成される。この電子のサイクロトロン共鳴により生成されるプラズマにより試料を処理する。

【００３４】磁場は、１０ガウス以上１１０ガウス以下、好ましくは１７ガウス以上７２ガウス以下の静磁場もしくは低周波（１ＫＨｚ以下）磁場の部分を有し、ガスは、０．４Ｐａないし４Ｐａの低圧とする。また、両電極間の距離を３０ないし１００㎜、好ましくは３０ないし６０㎜とする。なお、一対の電極は、それぞれ処理される試料の面積以上の面積を有するものであることは言うまでもない。

【００３５】高周波電源の周波数ｆとして、５０ＭＨｚ≦ｆ≦２００ＭＨｚのＶＨＦを用いることによって、プラズマ密度はマイクロ波ＥＣＲの場合に比べて１桁ないし２桁程度低下する。また、ガスの解離も低下し、不要なフッ素原子／分子や、イオンの発生も１桁程度以上低下する。このＶＨＦ帯の周波数と、サイクロトロン共鳴を用いることによって、プラズマ密度の絶対値として、5×10^{10} cm^{-3} 以上の、適度に密度の高いプラズマが得られ、０．４－４Ｐａの低圧で高レートの処理が可能となる。さらに、ガスの解離も過度に進まないために、ＳｉやＳｉＮ等の下地との選択比を大きく悪化させることは無い。

【００３６】従来の１３．５６ＭＨｚの平行平板電極に比べれば、ガスの解離が少し進むが、これによるフッ素原子／分子や、イオンのわずかの増加は、電極表面やチャンバ壁面にシリコンや炭素を含む物質を設置したり、更には、これらにバイアスを加えることや、水素を含むガスを用いて水素とフッ素を結合して排出することにより改善することができる。

【００３７】また、本発明によれば、両電極の間で、試料台に平行な磁場成分の最大となる部分を両電極の中央よりも試料台と反対側に設定し、試料台の試料載置面での試料に平行な磁場強度を３０ガウス以下好ましくは１５ガウス以下とすることによって、試料載置面付近で電子に働くローレンツ力（Ｅ×Ｂ）を小さい値にし、試料載置面でのローレンツ力による電子ドリフト効果によるプラズマ密度の不均一性の発生をなくすることができる。

【００３８】本発明の他の特徴によれば、試料の中央部付近に比べ、試料の周辺部ないしはその外側付近でプラズマの生成を高める様に、電子のサイクロトロン共鳴効果を中央に比べ、周辺部ないしはその外側で大きくする。電子のサイクロトロン共鳴効果を下げる手段としては、サイクロトロン共鳴領域と試料との距離を遠くしたり、サイクロトロン共鳴領域をなくしたり、磁場と電界との直交度合を少なくすること等により達成できる。

【００３９】また、サイクロトロン共鳴磁場ＢＣ付近での磁場勾配を急にし、ＥＣＲ共鳴領域を狭くすると、サイクロトロン共鳴効果を弱めることができる。ＥＣＲ共鳴領域は、Ｂｃ（１－ａ）≦Ｂ≦Ｂｃ（１＋ａ）　但し、０．０５≦ａ≦０．１なる磁場強度Ｂの範囲となる。

【００４０】ＥＣＲ共鳴領域では解離が進むため、特にイオンの生成が盛んになる。一方、ＥＣＲ共鳴領域以外の領域は、ＥＣＲ共鳴領域に比べて解離が進まず、ラジカルの生成の方が盛んになる。ＥＣＲ共鳴領域の幅と上部電極に加える高周波電力を調整することにより、試料の処理に適切なイオンとラジカルの発生をより独立に制御することができる。

【００４１】本発明の他の特徴は、真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、高周波電源を含むプラズマ生成手段とを有するプラズマ処理装置であって、前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、前記試料にパルスバイアス電圧を印加するパルスバイアス印加手段とを備え、前記高周波電源として１０MHｚ～５００MHｚの高周波電圧を印加するとともに、前記真空処理室を０．５～４．０Ｐａに減圧するように構成したことにある。

【００４２】本発明の他の特徴は、真空処理室と、該真空処理室で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、前記試料台に接続され、該試料台にパルスバイアス電圧を印加するパルスバイアス印加手段と、前記パルスバイアス電圧の印加に伴い前記静電吸着手段の静電吸着容量に対応して発生する電圧の変化を抑制する、電圧抑制手段とを設けたことにある。

【００４３】本発明の他の特徴は、真空処理室に設けられた対向する一対の電極の一方に試料を配置するステップと、該試料を静電吸着力によって前記電極に保持するステップと、前記試料が配置された雰囲気に、エッチングガスを導入するステップと、前記雰囲気を、０．５～４．０Ｐａに減圧排気するステップと、１０MHｚ～５００MHｚの高周波電圧を印加し、前記圧力下でエッチングガスをプラズマ化するステップと、該プラズマにより前記試料をエッチングするステップと、前記一方の電極にパルスバイアス電圧を印加するステップとからなるプラズマ処理方法にある。

【００４４】本発明の他の特徴は、対向する電極の一方の電極に試料を配置するステップと、該配置された試料を静電吸着力によって前記電極に保持するするステップ

と、前記試料が配置された雰囲気に、エッチングガスを導入するステップと、該導入されたエッチングガスをプラズマ化するステップと、該プラズマにより前記試料をエッチングするステップと、該エッチング時に前記一方の電極に、２５０Ｖ～１０００Ｖのパルス振幅と０．０５～０．４のデューティ比を有するパルスバイアス電圧を印加するステップからなり、前記試料中の絶縁膜（例えばＳｉO2, ＳｉＮ, ＢＰＳＧ等）をプラズマ処理することにある。

【００４５】本発明の他の特徴によれば、静電吸着用誘電体層を有する静電吸着手段を備えた試料台に所定の特性のパルス状バイアス電力を印加することにより、試料の温度制御性を十分に行ない、必要とする微細パターンの処理を安定して行うことが出来る。すなわち、試料を静電吸着力によって試料台に保持する静電吸着手段と、試料台に接続され、該試料台にパルスバイアス電圧を印加するパルスバイアス印加手段とを備えており、周期が０．２～２μｓで正方向パルス部分のｄｕｔｙが１／２以下のパルスバイアスを容量素子を介して試料に加える。

【００４６】また、本発明の他の特徴によれば、パルスバイアス電圧の印加に伴い静電吸着手段の静電吸着容量に対応して発生する電圧の変化を抑制する電圧抑制手段として、パルス一周期中の静電吸着により誘電体層の両端に加わる電圧変化が、パルスバイアス電圧の大きさの１／２以下となるように構成する。具体的には、下部電極の表面に設けられた誘電体の静電チャック膜の膜厚を薄くしたり、誘電体を比誘電率の大きい材料とする。あるいはまた、パルスバイアス電圧の周期を短くして誘電体層の両端に加わる電圧の上昇を抑制する方法を採用しても良い。

【００４７】本発明の他の特徴によれば、さらにまた、試料のエッチング時に前記一方の電極に、２５０Ｖ～１０００Ｖのパルス振幅と０．０５～０．４のデューティ比を有するパルスバイアス電圧を印加することにより、試料中の絶縁膜（例えばＳｉO2, ＳｉＮ, ＢＰＳＧ等）に対するプラズマ処理の選択性等を向上させることができる。

【００４８】本発明の他の特徴は、真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、プラズマ生成手段とを有するプラズマ処理装置であって、前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、前記試料にバイアス電圧を印加するバイアス印加手段と、前記真空処理室に、ラジカル発生用ガスを予め分解する手段を有し所望量のラジカルを供給するラジカル供給手段と、前記真空処理室にイオン発生用ガスを供給する手段と、前記真空処理室にプラズマを発生させるプラズマ生成手段とを具備し、前記試料としてＳｉO_2を用いることにある。

【００４９】本発明の他の特徴は、真空処理室と、該真空処理室内で処理される試料を配置するための試料台と、高周波電源を含むプラズマ生成手段とを有するプラズマ処理装置であって、前記試料を静電吸着力によって前記試料台に保持する静電吸着手段と、前記試料にパルスバイアス電圧を印加するパルスバイアス印加手段と、前記真空処理室に、ラジカル発生用ガスを予めプラズマ化し所望量のラジカルを供給するラジカル発生用プラズマ供給手段と、前記真空処理室に、イオン発生用ガスを供給しプラズマを発生させる前記プラズマ生成手段とを備え、前記高周波電源に１０MHz～５００MHzの高周波電圧を印加するとともに、前記真空処理室を０．５～４．０Ｐａに減圧するように構成されていることにある。

【００５０】本発明の他の特徴によれば、イオンとラジラルの量や質を独立に制御し、静電吸着用誘電体層を有する静電吸着手段を備えた試料台に所定の特性のパルス状バイアス電力を印加することにより、試料の温度制御性を十分に行ない、必要とする微細パターンの処理を安定して行うことが出来る。

【００５１】さらに、イオンとラジラルの量や質を独立に制御し、狭いイオンエネルギー分布を得て、安定して制御性良くプラズマ処理の選択性等を向上させることができる。

【００５２】また、イオンとラジラルの量や質を独立に制御し、パルスバイアス電圧の印加に伴い静電吸着手段の静電吸着容量に対応して発生する電圧の変化を抑制する電圧抑制手段として、パルス一周期中の静電吸着により誘電体層の両端に加わる電圧変化が、パルスバイアス電圧の大きさの１／２以下となるように構成する。具体的には、下部電極の表面に設けられた誘電体の静電チャック膜の膜厚を薄くしたり、誘電体を比誘電率の大きい材料とする。あるいはまた、パルスバイアス電圧の周期を短くして誘電体層の両端に加わる電圧の上昇を抑制する方法を採用しても良い。

【００５３】また、本発明の他の特徴によれば、イオンとラジラルの量や質を独立に制御し、試料のエッチング時に前記一方の電極に、２５０Ｖ～１０００Ｖのパルス振幅と０．０５～０．４のデューティ比を有するパルスバイアス電圧を印加することにより、試料中の絶縁膜（例えばＳｉO2, ＳｉＮ, ＢＰＳＧ等）に対する下地とのプラズマ処理の選択性等を向上させることができる。

【００５４】さらに本発明の他の特徴によれば、イオンとラジラルの量や質を独立に制御し、プラズマ発生用の高周波電源として、１０MHｚ～５００MHｚの高周波電圧を用い、処理室内のガス圧力を、０．５～４．０Ｐａの低圧としている。これにより、安定したプラズマが得られる。また、このような高周波電圧を用いることによりガスプラズマの電離がよくなり、試料加工時の選択比制御が良くなる。

【００５５】

【発明の実施の形態】以下本発明の実施例を説明する。まず図１に、本発明を対向電極型のプラズマエッチング装置へ適用した第一の実施例を示す。図１において、真空容器としての処理室１０は、上部電極１２と下部電極１５とから成る一対の対向する電極を備えている。下部電極１５には試料４０が載置される。両電極１２，１５の間隙は、φ３００mm以上の大口径の試料を処理する時の試料面上の圧力差を１割以下にするために、３０mm以上とするのが望ましい。また、フッ素原子や分子やイオンを減じるために、上部／下部電極表面上での反応を有効に活用する観点から、１００mm以下、好ましくは６０mm以下とするのが望ましい。上部電極１２には、マッチングボックス１６２を介して高周波エネルギーを供給する高周波電源１６が接続されている。１６１は高周波電源変調信号源である。上部電極１２とアース間には、バイアス電源１７の周波数成分に対しては低インピーダンスとなり、高周波電源１６の周波数成分に対しては高インピーダンスとなるフィルタ１６５が接続されている。

【００５６】試料台にほぼ平行に設置された上部電極１２の表面積は、処理される試料４０の面積よりも大きくし、バイアス電源１７の印加により試料面上のシースに効率良くかつ均一に電圧が加わるように構成している。

【００５７】上部電極１２の下側表面には、シリコン、カーボンもしくはＳｉＣからなるフッ素の除去板としての上部電極カバー３０が設けられている。また、上部電極１２の上部には、ガスを所望の分布に拡散するガス拡散板３２を備えたガス導入室３４が設けられている。処理室１０には、ガス供給部３６からガス導入室３４のガス拡散板３２、上部電極１２及び上部電極カバー３０に設けられた孔３８を介して、試料のエッチング等の処理に必要なガスが供給される。外室１１は、外室にバルブ１４を介して接続された真空ポンプ１８により真空排気され、処理室１０が試料の処理圧力に調整される。１３は絶縁体である。処理室１０の周囲には、プラズマ密度を高めると共に処理室中の反応の均質化を図るために、放電止じ込め用リング３７が設けられている。放電止じ込め用リング３７には、排気用の隔間を設けている。

【００５８】上部電極１２の上には、電極間に形成された電界Ｅに直交し、試料４０の面に平行な磁場を形成するための磁場形成手段２００が設けられている。磁場形成手段２００は、コア２０１、電磁コイル２０２、絶縁体２０３を具備している。上部電極１２の構成材料としては、非磁性材導電体、例えばアルミニウムやアルミニウム合金がある。処理室１０の構成材料としては、非磁性材、例えばアルミニウムやアルミニウム合金、アルミナ、石英、ＳｉＣ等がある。コア２０１は、磁束が処理室１０の中央上部から上部電極１２に向かい、上部電極１２に沿って略平行に外周に伸びるような磁界Ｂを形成すべく、コア部２０１Ａ、２０１Ｂを有する断面略Ｅ字型の軸回転対称構造となっている。磁場形成手段２００によって両電極間に形成される磁場は、１０ガウス（Ｇａｕｓｓ）以上１１０ガウス以下、好ましくは１７ガウス以上７２ガウス以下の静磁場、あるいは低周波磁場（１KHZ以下）の、サイクロトロン共鳴を生じる部分を有する。

【００５９】サイクロトロン共鳴を生じる磁場強度Bc(ガウス)は、公知の通り、プラズマ生成用高周波の周波数ｆ（ＭＨｚ）に対しBc＝０．３５７×ｆ（ＭＨｚ）の関係にある。

【００６０】なお、本発明における２電極１２，１５は、相対向する一対の電極が実質的に平行であれば良く、プラズマ生成特性等の要求から電極１２，１５が若干の凹面あるいは凸面を持つものであっても良い。この様な２電極型では、電極間の電界分布を容易に均一化でき、この電界に直交する磁場の均一性を向上することにより、サイクロトロン共鳴によるプラズマの生成を均一にすることが比較的容易である特徴を持つ。

【００６１】試料４０を載置保持する下部電極１５は、２極式の静電チャック２０を備えた構成となっている。すなわち、下部電極１５は、外側の第１下部電極１５Ａと、その内側上方に絶縁体２１を介して配置された第２下部電極１５Ｂによって構成され、第１、第２両下部電極の上表面に静電吸着用誘電体層（以下、静電吸着膜と略称する）２２が設けられている。第１、第２両下部電極間には、高周波成分カット用のコイル２４Ａ，２４Ｂを介して直流電源２３が接続されており、第２下部電極１５Ｂ側が正になるようにして両下部電極間に直流電圧を印加する。これにより、静電吸着膜２２を介して試料４０と両下部電極間に作用するクーロン力により、試料４０が下部電極１５上に吸着、保持される。静電吸着膜２２としては、例えば、酸化アルミニウム、酸化アルミニウムにチタン酸化物を混合したものなどの誘電体を使用することができる。また、電源２３としては、数１００Ｖの直流電源を用いる。

【００６２】また、下部電極１５（１５Ａ，１５Ｂ）には、２０Ｖ～１０００Ｖの振幅のパルスバイアスを供給するパルスバイアス電源１７が、ＤＣ成分をカットするブロッキングコンデンサ１９Ａ，１９Ｂを介してそれぞれ接続されている。

【００６３】これまで、静電チャックとして、２極式を用いて説明したが、他の方式の静電チャック、例えば、単極式やｎ極式（ｎ≧３）でもよい。

【００６４】エッチング処理を行う場合、処理の対象物である試料４０は、処理室１０の下部電極１５の上に載置され、静電チャック２０により吸着される。一方、ガス供給部３６からガス導入室３４を介して、試料４０のエッチング処理に必要なガスが処理室１０に供給される。外室１１は真空ポンプ１８により真空排気され、処理室１０が試料の処理圧力、例えば０．４～４．０Ｐａ

（パスカル）になるように減圧排気される。次に、高周波電源１６より３０MHｚ～３００MHｚ、望ましくは５０MHｚ～２００MHｚの高周波電力を出力して、処理室１０の処理ガスをプラズマ化する。

【００６５】３０ないし３００ＭＨｚの高周波電力と磁場形成手段２００により形成された１０ガウス以上１１０ガウス以下の静磁場の部分とにより、上部電極１２と下部電極１５との間に電子のサイクロトロン共鳴を生じさせ、この場合、０．４～４．０Ｐａの低ガス圧でかつ高い密度のプラズマを生成させる。

【００６６】他方、下部電極１５に、パルスバイアス電源１７から電圧２０Ｖ～１０００Ｖで周期が０．１μs～１０μs、好ましくは、０．２μs～５μsで正のパルス部分のデューティが０．０５～０．４のバイアスを印加し、プラズマ中の電子やイオンを制御して試料４０に対するエッチング処理を行う。

【００６７】エッチングガスは、ガス拡散板３２で所望の分布にされた後、上部電極１２及び上部電極カバー３０に明けられた孔３８を通して処理室１０に注入される。

【００６８】また上部電極カバー３０には、カーボンやシリコンあるいはこれらを含有するものを用い、フッ素や酸素成分を除去してレジストやシリコン等の下地との選択比を向上させる。

【００６９】大口径の試料の微細加工性を向上させるには、プラズマ発生用高周波電源１６としてより高い周波数のものを用い、低ガス圧領域での放電の安定化を図るのがよい。本発明では、０．４Ｐａないし４Ｐａの低圧ガスで5×10^{10}ないし5×10^{11} cm^{-3}のプラズマ密度で、かつ、過度にガスの解離を進めず大口径で均一なプラズマを得るために、上部電極１２に、プラズマ生成用高周波電源１６を接続する。他方、試料を載置した下部電極１５には、イオンエネルギー制御用のバイアス電源１７を接続しこれら両電極間の距離を、３０ないし１００mmとする。

【００７０】また、プラズマ生成用高周波電源１６として、３０ＭＨｚないし３００ＭＨｚ，好ましくは５０ＭＨｚないし２００ＭＨｚのＶＨＦを用い、１０ガウス以上１１０ガウス以下、好ましくは１７ガウス以上７２ガウス以下の静磁場もしくは低周波（１ＫＨｚ以下）磁場の部分との相互作用により、上部電極１２と下部電極１５の間に、電子のサイクロトロン共鳴を生じさせる。

【００７１】図２に、電子のサイクロトロン共鳴を生じる磁場を加えた状態で、プラズマを発生させる高周波電源の周波数を変化させたときの、プラズマ密度の変化の一例を示す。供試ガスはアルゴンにC_4F_8を２～１０％加えたもの、処理室の圧力は１Ｐａである。プラズマ密度は、ｆ＝２４５０ＭＨｚのマイクロ波ＥＣＲの場合を１として基準値化している。なお、破線は、磁場無しの場合を示している。

【００７２】５０ＭＨｚ≦ｆ≦２００ＭＨｚにおいては、プラズマ密度は、マイクロ波ＥＣＲの場合に比べて１桁程度ないし２桁程度低下する。また、ガスの解離も低下し、不要なフッ素原子／分子や、イオンの発生も１桁以上低下する。このＶＨＦ帯の周波数と、サイクロトロン共鳴を用いることによって、プラズマ密度の絶対値として、5×10^{10} cm^{-3}以上の、適度に密度の高いプラズマが得られ、０．４－４Ｐａの低圧で高レートの処理が可能となる。さらに、ガスの解離も過度に進まないために、SiO_2等の絶縁膜に対してＳｉやＳｉＮ等の下地との選択比を大きく悪化させることは無い。

【００７３】５０ＭＨｚ≦ｆ≦２００ＭＨｚにおいては、従来の１３．５６ＭＨｚの平行平板電極に比べて、ガスの解離が少し進むが、これによるフッ素原子／分子や、イオンのわずかの増加は、電極表面やチャンバ壁面にシリコンや炭素を含む物質を設置して改善することができる。あるいは更に、この電極表面やチャンバ壁面にバイアスを加えることにより、フッ素を炭素やシリコンと化合させて排出したり、水素を含むガスを用いて水素とフッ素とを化合させて排出して改善することができる。

【００７４】高周波電源の周波数が２００ＭＨｚ以上、特に３００ＭＨｚ以上になると、プラズマ密度が高くなるが、ガスの解離が過度になりフッ素原子／分子やイオンの増加が大きくなり過ぎ、ＳｉやＳｉＮ等の下地との選択比を大きく悪化させるので好ましくない。

【００７５】図３に、サイクロトロン共鳴時と無共鳴時とに電子が高周波電界から得るエネルギー利得ｋを示す。無磁場時に高周波の１周期中に電子が得るエネルギーをｅ0とし、サイクロトロン共鳴磁場 $B_c=2\pi f\cdot(m/e)$ を印加した時に高周波の１周期中に電子が得るエネルギーを ｅ1としたとき、ｅ1，ｅ0は、数1のようになる。

【００７６】

【数１】

$$e_0=\frac{e^2E^2}{2m}\left(\frac{\nu}{\omega^2+\nu^2}\right)$$

$$e_1=\frac{e^2E^2D}{4m}\left(\frac{1}{\nu^2+(\omega-\omega c)^2}+\frac{1}{\nu^2+(\omega+\omega c)^2}\right)\cdots\cdots \text{数1}$$

但し、Ｅは電界強度

【０077】これらの比（＝e1／e0）をｋとしたとき、ｋは、次式で表される。但し、ｍ：電子の質量，ｅ：電子の電荷，ｆ：印加周波数

$K=(1/2)(\nu^2+\omega^2)\ [1/(\nu^2+(\omega-\omega c)^2))+(1/(\nu^2+(\omega+\omega c)^2))]$

但し、ν：衝突周波数，　ω：励起角周波数，ωc：サイクロトロン角周波数

一般に、ｋの値は、ガス圧が低い程、周波数が高い程大きくなる。図３は、Ａｒ（アルゴン）ガスの場合であり、圧力Ｐ＝１Ｐａにおいては、ｆ≧５０ＭＨｚでｋ≧１５０となり、磁場が無い時に比べて低ガス圧下においても解離が促進される。サイクロトロン共鳴効果は、圧力Ｐ＝１Ｐａにおいては、２０ＭＨｚ程度以下の周波数では急速に小さくなる。図２に示した特性でも分かるように、３０ＭＨｚ以下の周波数では、磁場無しの場合と差が少なく、サイクロトロン共鳴効果は小さい。

【００７８】なお、ガス圧を低くすればサイクロトロン共鳴効果は高まるが、１Ｐａ以下ではプラズマの電子温度が高まり、解離が進み過ぎるという逆効果が大きくなる。ガスの過度の解離を抑えて、かつ、プラズマ密度を5×10^{10} cm^{-3}程度以上にするには、ガスの圧力として０．４Ｐａから４Ｐａ、好ましくは１Ｐａ程度から４Ｐａの間が良い。

【００７９】サイクロトロン共鳴効果を発揮させるためには、ｋの値を数十以上とする必要がある。図２や図３からも明らかなように、過度にガスの解離を進めずにサイクロトロン共鳴効果を有効に利用するには、ガス圧が０．４Ｐａないし４Ｐａの圧力では、プラズマ生成用高周波電源として、３０ないし３００ＭＨｚ，好ましくは５０ないし２００ＭＨｚのＶＨＦを用いる必要がある。

【００８０】図４は、従来のマグネトロン方式チャンバで上部電極を接地し、下部電極上に均一な横方向の磁界Ｂを与えると共に、６８ＭＨｚの高周波電力を印加した時の、試料に誘起されるイオン加速電圧ＶDCと、試料内の誘起電圧ＶDCのバラツキΔＶを示している。磁場Ｂの強度を上げると電子に働くローレンツ力によりイオン加速電圧ＶDCが小さくなり、プラズマ密度が増加する。しかし、従来のマグネトロン放電型の場合、磁場Ｂの強度が２００ガウス程度と大きいため、プラズマ密度の面内の均一性が悪化し、誘起電圧のバラツキΔＶが大きくなり、試料のダメージが増大する欠点がある。

【００８１】図４から、従来のマグネトロン放電型の２００ガウスの場合に比べ、ΔＶを１／５～１／１０以下にするには、磁場Ｂの強度は、試料面付近において３０ガウス以下、好ましくは１５ガウス以下の小さな値とするのが、ダメージを無くす上から望ましい。

【００８２】サイクロトロン共鳴領域は、上部電極１２と下部電極１５の中間で、かつ両電極の中間位置よりもやや上部電極側に形成される。図５は、横軸が試料面（下部電極１５）から上部電極１２までの距離、縦軸が磁場を示している。図５の例は、印加周波数ｆ1＝１００ＭＨｚ，Ｂｃ＝３７．５Ｇ、電極間隔＝５０㎜の条件で、ＥＣＲ領域が、試料面から３０ｍｍ付近に形成されている。

【００８３】このように本発明では、上部電極１２と下部電極１５との間で、下部電極１５（試料載置面）に平行な磁場成分の最大となる部分を、上部電極面、もしくは両電極の真中より上部電極側に設定する。これによって、下部電極面での試料に平行な磁場強度を３０ガウス以下好ましくは１５ガウス以下として、下部電極面付近で電子に働くローレンツ力（Ｅ×Ｂ）を小さい値とし、下部電極面でのローレンツ力による電子ドリフト効果によるプラズマ密度の面内の不均一性の発生をなくすことができる。

【００８４】図１の実施例の磁場形成手段２００によれば、図６に示すように、ＥＣＲ領域が試料の中央部付近を除き、下部電極１５（試料載置面）からほぼ同じ高さの位置に形成される。従って、大口径の試料に対して、均一なプラズマ処理を行うことが出来る。ただし、試料の中心付近では、ＥＣＲ領域が試料載置面から高い位置に形成されている。ＥＣＲ領域と試料台間は、３０㎜以上の距離があるため、この間でイオンやラジカル試は拡散し平均化されるので、通常のプラズマ処理には問題が無い。ただし、試料の全面を均一にプラズマ処理するためには、ＥＣＲ領域が試料の全面に亘り試料面から同じ高さの位置に、あるいは試料の外側のＥＣＲ領域が中心付近のＥＣＲ領域よりも若干試料台側に近くなるように形成されるのが望ましい。この対策については、後で詳細に述べる。

【００８５】以上述べたように、図１に示す本発明の実施例では、プラズマ発生用高周波電源１６として、３０ないし３００ＭＨｚの高周波電力を用い、かつ電子サイクロトロン共鳴によりガスの解離を進めているため、処理室１０内のガス圧力が０．４Ｐａないし４Ｐａの低圧の下でも安定したプラズマが得られる。また、シース中でのイオンの衝突が少なくなるので、試料４０の処理に際して、イオンの方向性が増し垂直な微細加工性を向上させることができる。

【００８６】処理室１０の周囲は、放電止じ込め用リング３７によってプラズマを試料４０付近に極在化させることにり、プラズマ密度の向上を図ると共に、放電止じ込め用リング３７より外の部分への不要なデポジット物の付着を最小とさせる。

【００８７】なお、放電止じ込め用リング３７としては、カーボンやシリコンあるいはＳｉＣ等の半導体や導電材を用いる。この放電止じ込め用リング３７を高周波電源に接続しイオンによるスパッタを生じさせると、リング３７へのデポ付着を低減すると共にフッ素の除去効果も持たせることができる。

【００８８】なお、試料４０の周辺の絶縁体１３上に、

カーボンやシリコンあるいはこれらを含有するサセプタカバー３９を設けると、SiO_2等の絶縁膜をフッ素を含有するガスを用いてプラズマ処理を行う場合、フッ素を除去出来るので、選択比の向上に役立つ。この場合、バイアス電源１７の電力の一部がサセプタカバー３９に印加されるように、サセプタカバー３９の下部分の絶縁体１３の厚みを０．５㎜～５㎜程度に薄くすると、イオンによるスパッタ効果により上記効果が促進される。

【００８９】また、直流電源２３の電位により、誘電体の静電吸着膜２２を挟んで下部電極１５（１５Ａ，１５Ｂ）と試料４０を介して静電吸着回路が形成される。この状態で試料４０は静電気力により下部電極１５に係止、保持される。静電気力により係止された試料４０の裏面には、ヘリウム、窒素、アルゴン等の熱伝導ガスが供給される。熱伝導ガスは、下部電極１５の凹部に充填されるが、その圧力は、数百パスカルから数千パスカル程度とする。なお、静電吸着力は、ギャップが設けられた凹部の間では、ほとんどゼロであり、下部電極１５の凸部においてのみ静電吸着力が発生しているとみなせる。しかし、後で述べるように、直流電源２３に電圧を適切に設定して、熱伝導ガスの圧力に十分耐えることのできる吸着力を設定することができるので、熱伝導ガスにより試料４０が動いたり飛ばされたりすることはない。

【００９０】ところで、静電吸着膜２２は、プラズマ中のイオンに対するパルスバイアスのバイアス作用を減じる様に作用する。正弦波電源を用いてバイアスをしている従来の方法でもこの作用は生じているが、顕在化していない。しかし、パルスバイアスではイオンエネギー幅が狭いという特徴が犠牲になってしまうため、問題が大きくなる。

【００９１】本発明では、パルスバイアスの印加に伴い静電吸着膜２２の両端間に発生する電圧の上昇を抑制し、パルスバイアスの効果を高めるために、電圧抑制手段を設けたことに１つの特徴がある。

【００９２】電圧抑制手段の一例としては、パルスバイアスの印加に伴い静電吸着膜の両端間に生ずるバイアス電圧の一周期中の電圧の変化（V_{CM}）が、パルスバイアス電圧の大きさ(V_p)の１／２以下となるように構成するのが良い。具体的には、下部電極１５の表面に設けられた誘電体からなる静電吸着膜の膜厚を薄くしたり、誘電体を誘電率の大きい材料とすることにより、誘電体の静電容量を増す方法がある。

【００９３】あるいはまた、他の電圧抑制手段として、パルスバイアス電圧の周期を短くして電圧V_{CM}の上昇を抑制する方法もある。さらに、静電吸着回路とパルスバイアス電圧印加回路を別な位置、例えば試料が配置保持される電極とは別の対向する電極、あるいは別に設けた第三の電極に、分離して設ける方法も考えられる。

【００９４】次に、図７～図１３を用いて、本発明における電圧抑制手段によりもたらされるべき、パルスバイアス一周期中の静電吸着膜の両端間に生じる電圧の変化（V_{CM}）とパルスバイアス電圧の関係について詳細に述べる。

【００９５】まず、本発明のパルスバイアス電源１７において使用する望ましい出力波形の例を図７に示す。図中、パルス振幅：v_p，パルス周期：T_0，正方向パルス幅：T_1 とする。

【００９６】図７（Ａ）の波形をブロッキングコンデンサ，静電吸着用誘電体層（以下、静電吸着膜と略称する）を経由して試料に印加した時、別の電源によりプラズマを発生させた状態での定常状態での試料表面の電位波形を図７（Ｂ）に示す。

ただし、波形の直流成分電圧　：V_{DC}

プラズマのフローティングポテンシャル：V_f

静電吸着膜の両端間に生じる電圧の一周期中の最大電圧：V_{CM}

とする。

【００９７】図７（Ｂ）中、V_f より正電圧となっている（Ｉ）なる部分は、主に電子電流のみを引き込んでいる部分であり、V_f より負の部分は、イオン電流を引き込んでいる部分，V_f の部分は、電子とイオンとがつりあっている部分（V_f は通常数Ｖ～十数Ｖ）である。

【００９８】なお、図７（Ａ）および今後の説明では、ブロッキングコンデンサの容量や試料表面近辺の絶縁体による容量は静電吸着膜による容量（以下静電吸着容量と略称する）に比べて十分大きいと仮定している。V_{CM}の値は次の式（数２）で表わされる。

【００９９】

【数２】

$$V_{CM}=\frac{q}{c}=\frac{i_i\times(T_0-T_1)}{(\varepsilon_r\varepsilon_0/d)\times K} \quad \cdots\cdots \text{数2}$$

【０１００】但し、ｑ：(T_0-T_1) 期間に試料に流入するイオン電流密度（平均値）

ｃ：単位面積当りの静電吸着容量（平均値）

i_i ：イオン電流密度，　ε_r ：静電吸着膜の比誘電率

ｄ：静電吸着膜の膜厚　ε_0 ：真空中の誘電率（定数）

Ｋ：静電吸着膜の電極被覆率（≦１）

図８及び図９に、パルスデューティ比：(T_1/T_0) は一定のままT_0 を変化させた時の試料表面の電位波形とイオンエネルギーの確率分布を示す。但し、T_{01}，T_{02}：T_{03}：T_{04}：T_{05}＝１６：８：４：２：１とする。

【０１０１】図８の（１）に示す様に、パルス周期T_0が大きすぎると、試料表面の電位波形は矩形波から大きくはずれ、三角波になり、イオンエネルギーは図９に示

すように、低い方から高い方まで一定の分布となり好ましくない。

【０１０２】図８の（２）～（５）に示す様に、パルス周期T_0を小さくするにつれて、（V_{CM}／v_p）は１よりも小さな値となり、イオンエネルギー分布も狭くなってゆく。

【０１０３】図８，図９においてT_0＝T_{01}，T_{02}，T_{03}，T_{04}，T_{05}は、（V_{CM}／v_p）＝１，０．６３，０．３１，０．１６，０．０８に対応している。次に、パルスのオフ（T_0－T_1）期間と、静電吸着膜の両端間に生じる電圧の一周期中の最大電圧V_{CM}の関係を図１０に示す。

【０１０４】静電吸着膜として、厚み０．３mmの酸化チタン含有アルミナ（ε_r＝１０）を用いて電極の約５０％を被膜（Ｋ＝０．５）した場合、イオン電流密度i_i＝５ｍＡ／cm^2の中密度プラズマ中でのV_{CM}の値の変化を図１０の太線（標準条件の線）で示す。

【０１０５】図１０から明らかなように、パルスのオフ（T_0－T_1）期間が大きくなるにつれ、静電吸着膜の両端間に生じる電圧V_{CM}はそれに比例して大きな値となり、通常使用されるパルス電圧v_p以上になってしまう。

【０１０６】例えば、プラズマエッチング装置においては、ダメージ，下地やマスクとの選択性，形状等により通常、

ゲートエッチングでは　２０volt ≦ v_p ≦１００volt

メタルエッチングでは　５０volt ≦ v_p ≦２００volt

酸化膜エッチングでは　２５０volt ≦ v_p ≦１０００volt

に制限される。

【０１０７】後述の（V_{CM}／v_p）≦０．５の条件を満たそうとすると標準状態では、（T_0－T_1）の上限は次のようになる。

ゲートエッチングでは　（T_0－T_1）≦０．１５μｓ

メタルエッチングでは　（T_0－T_1）≦０．３５μｓ

酸化膜エッチングでは　（T_0－T_1）≦１．２μｓ

ところで、T_0が０．１μｓ に近くなると、イオンシースのインピーダンスがプラズマのインピーダンスに近づくかそれ以下となるため、不要なプラズマの発生を生じると共に、バイアス電源がイオンの加速に有効に使われなくなってくる。このため、バイアス電源によるイオンエネルギーの制御性が悪化するため、T_0は、０．１μｓ以上、好ましくは０．２μｓ以上が良い。

【０１０８】従って、v_pを低くおさえられるゲートエッチャ等においては、静電吸着膜の材料を比誘電率が１０～１００と高いもの、（例えばTa_2O_3でε_r＝２５）に変えたり、絶縁耐圧を低下させず膜厚を薄く、例えば１０μｍ～４００μｍ、望ましくは１０μｍ～１００μｍにしたりする必要がある。

【０１０９】図１０には、単位面積当りの静電容量ｃを、それぞれ２．５倍、５倍、１０倍に増加させた時のV_{CM}の値も併記した。静電吸着膜の改善を行っても現状では静電容量ｃを数倍にする改善が限度とみられ、V_{CM}≦３００ volt、ｃ≦１０c_0とすると、０．１μｓ≦（T_0－T_1）≦１０μｓとなる。イオンの加速によりプラズマ処理に有効な部分は（T_0－T_f）の部分であり、パルスデューティ（T_1／T_0）としてはできるだけ小さい方が好ましい。

【０１１０】時間平均も加味した、プラズマ処理の効率として（V_{DC}／v_p）で見積ったのが、図１１である。（T_1／T_0）を小さくし、（V_{DC}／v_p）を大きくするのが好ましい。

【０１１１】プラズマ処理の効率として０．５≦（V_{DC}／v_p）を仮定し、後述の条件、（V_{CM}／v_p）≦０．５を入れると、パルスデューディは、（T_1／T_0）≦０．４程度となる。

【０１１２】なお、パルスデューディ（T_1／T_0）は小さいほどイオンエネルギーの制御に有効であるが、必要以上に小さくするとパルス幅T_1が０．０５μｓ程度の小さい値となり、数十MHzの周波数成分を多く含むようになり、後述するような、プラズマ発生用高周波成分との分離も難しくなる。図１１に示すように、０≦（T_1／T_0）≦０．０５間での（V_{DC}／v_p）の低下はわずかであり、（T_1／T_0）として０．０５以上で特に問題は生じない。

【０１１３】ここで図１２に、ゲートエッチングの例として、塩素ガス１．３Ｐａをプラズマ化した時のシリコンと下地の酸化膜とのエッチングレートＥＳｉおよびＥSiO_2のイオンエネルギー依存性を示す。シリコンのエッチングレートＥＳｉは低イオンエネルギーでは一定値になる。イオンエネルギーが１０Ｖ程度以上では、イオンエネルギーの増加に従って、ＥＳｉも増加する。一方下地となる酸化膜のエッチングレートＥSiO_2は、イオンエネルギーが２０Ｖ程度以下では０であり、２０Ｖ程度を越えると、イオンエネルギーと共にＥSiO_2は増加する。

【０１１４】その結果、イオンエネルギーが２０Ｖ程度以下では下地との選択比ＥＳｉ／ＥSiO_2が∞となる領域が存在する。イオンエネルギーが２０Ｖ程度以上では、下地との選択比ＥＳｉ／ＥSiO_2は、イオンエネルギーの増加と共に急速に低下する。

【０１１５】図１３は、絶縁膜の一種である酸化膜（SiO_2，ＢＰＳＧ，ＨＩＳＯ等）のエッチングの例として、Ｃ４Ｆ８ガス１．０Ｐａをプラズマ化した時の、酸化膜とシリコンとのエチングレートＥSiO_2および、ＥＳｉのイオンエネルギー分布を示すものである。

【０１１６】酸化膜のエッチングレートＥSiO_2は、低イオンエネルギーでは負の値となり、デポを生じる。

イオンエネルギーが４００Ｖ付近にてＥＳｉO_2が急速に正に立ち上がり、その後は、徐々に増加する。一方下地となるシリコンのエッチングレートＥＳｉは、ＥＳｉO_2よりイオンエネルギーの高い所で(－)（エッチング）から(＋)（エッチング）となり徐々に増加する。

【０１１７】この結果、ＥＳｉO_2が(－)から(＋)に変化する付近にて、下地との選択比ＥＳｉO_2／ＥＳｉが∞ となり、それ以上でＥＳｉO_2／ＥＳｉはイオンエネルギーの増加と共に急速に低下する。

【０１１８】図１２、図１３で、実際のプロセスへの適用に対しては、ＥＳｉやＥＳｉO_2の値や、ＥＳｉ／ＥＳｉO_2や、ＥＳｉO_2／ＥＳｉの値の大きさを考慮して、バイアス電源を調整してイオンエネルギーを適正値にする。

【０１１９】また、ジャストエッチング（下地膜が現われるまでのエッチング）まではエッチングレートの大きさを優先し、ジャストエッチ後は選択比の大きさを優先してイオンエネルギーをジャストエッチの前後に変更すれば、更に良い特性が得られる。

【０１２０】ところで図１２、図１３に示した特性は、イオンのエネルギー分布が狭い部分に限定された時の特性である。イオンのエネルギー分布が広い場合の各エッチングレートはその時間平均値となるため、最適値に設定することが出来ず、選択比は大幅に低下してしまう。

【０１２１】実験によると、（V_{DC}／v_p）は０．３以下程度であれば、イオンエネルギーの広がりは±１５％程度以下となり、図１２や図１３の特性でも３０以上の高い選択比が得られた。また、（V_{DC}／v_p）≦０．５であれば、従来の正弦波バイアス法に比べて選択比等の改善が図れた。

【０１２２】このように、静電吸着膜の両端間に生じるパルス電圧の一周期中の電圧変化(V_{CM})を抑える電圧抑制手段として、V_{CM}が、パルスバイアス電圧の大きさv_pの１／２以下となるように構成するのが良く、具体的には、下部電極１５の表面に設けられた誘電体の静電チャック膜２２の膜厚を薄くしたり、誘電体を誘電率の大きい材料とすることにより、誘電体の容量を増すことができる。あるいは、パルスバイアス電圧の周期を、０．１μｓ～１０μｓ、好ましくは０．２μｓ～５μｓ（繰り返し周波数：０．２MHz～５MHzに対応）と短くし、パルスデューティ（T_1／T_0）を、０．０５≦（T_1／T_0）≦＝０．４として静電吸着膜の両端の電圧変化を抑制する。

【０１２３】あるいはまた、上記誘電体の静電吸着膜の膜厚と、誘電体の比誘電率及びパルスバイアス電圧の周期の幾つかを組み合わせて、静電吸着膜の両端間に生じる電圧V_{CM}の変化が上記した（V_{CM}／v_p）≦０.５の条件を満たすようにしても良い。

【０１２４】次に、図１の真空処理室を、絶縁膜（例えばＳｉO2，ＳｉＮ，ＢＰＳＧ等）のエッチングに用いた実施例について述べる。

【０１２５】ガスとしては、C_4Ｆ８：１～５％，Ａｒ：９０～９５％，O_2：０～５％もしくは、C_4Ｆ８：１～５％，Ａｒ：７０～９０％，O_2：０～５％，ＣＯ：１０～２０％，の組成のものを用いる。プラズマ発生用高周波電源１６としては、従来よりも高い周波数、例えば４０ＭＨｚのものを用い、１～３Ｐａの低ガス圧領域での放電の安定化を計る。

【０１２６】なお、プラズマ源用高周波電源１６の高周波化により必要以上の解離が進行する場合は、高周波電源１６の出力を高周波電源変調信号源１６１により、オンオフないしはレベル変調制御する。高レベルの時は、ラジカルの生成に比べてイオンの生成が盛んとなり、低レベルの時は、イオンの生成に比べてラジカルの生成が盛んとなる。オン（またはレベル変調時の高レベル）時間としては５～５０μｓ程度、オフ時間（またはレベル変調時の低レベル）としては１０～１００μｓ、周期２０μｓ～１５０μｓ程度を用いる。これにより不必要な解離を防ぐとともに、所望のイオン－ラジカル比を得ることができる。

【０１２７】また、プラズマ源用高周波電源の変調周期は、通常、パルスバイアスの周期に比べ長くなる。そこで、プラズマ源用高周波電源の変調周期をパルスバイアスの周期の整数倍にし、２つの間の位相を最適化することにより、選択比の改善ができた。

【０１２８】一方、パルスバイアス電圧の印加によって、プラズマ中のイオンを試料に加速、垂直入射させることにより、イオンエネルギーの制御を行う。パルスバイアス電源１７として、例えば、パルス周期：Ｔ＝０．６５μｓ、パルス幅：T_1＝０．１５μｓ、パルス振幅：Ｖｐ＝８００Ｖの電源を用いることにより、イオンエネルギーの分布幅は±１５％以下になり、下地のＳｉやＳｉＮとの選択比として２０～５０の特性の良いプラズマ処理が可能になった。

【０１２９】次に、図１４により本発明の他の実施例になる２電極型のプラズマエッチング装置を説明する。この実施例は、図１に示したと同様な構成であるが、試料４０を保持する下部電極１５が、単極式の静電チャック２０を備えた構成となっている点で異なる。下部電極１５の上表面に静電吸着用誘電体層２２が設けられ、下部電極１５には、高周波成分カット用のコイル２４を介して直流電源２３のプラス側が接続されている。また、２０Ｖ～１０００Ｖの正のパルスバイアスを供給するパルスバイアス電源１７が、ブロッキングコンデンサ１９を介して接続されている。

【０１３０】処理室１０の周囲には放電止じ込め用リング３７Ａ，３７Ｂを設置し、プラズマ密度の向上を図ると共に、放電止じ込め用リング３７Ａ，３７Ｂ外の部分への不要なデポジット物の付着を最小とさせる。図１４の放電止じ込め用リング３７Ａ，３７Ｂにおいて、下部

電極側の放電止じ込め用リング３７Ａの土手部の直径は、上部電極側の放電止じ込め用リング３７Ｂの土手部の直径より小さくし、試料周辺での反応生成物の分布を一様にしている。

【０１３１】なお、放電止じ込め用リング３７Ａ，３７Ｂの材料として、少なくとも処理室側に面する側に、カーボン、シリコンあるいはＳｉＣ等の半導体や導電体を用いる。また、下部電極側リング３７Ａにはコンデンサ１９Ａを介して１００Ｋ～１３．５６ＭＨｚの放電止じ込めリング用バイアス電源１７Ａを接続し、上部電極側リング３７Ｂには高周電源１６の電力の一部が印加される様に構成し、イオンのスパッタ効果によるリング３７Ａ，３７Ｂへのデポ付着を低減すると共にフッ素の除去効果も持たせる。

【０１３２】なお、図１４の１３Ａ，１３Ｃはアルミナ等で構成される絶縁体であり、１３ＢはＳｉＣ，グラッシーカーボン、Ｓｉ等の導電性を有する絶縁体である。

【０１３３】リング３７Ａ，３７Ｂの導電性が低い場合には、金属等の導体をリング３７Ａ，３７Ｂ中に内蔵させリングの表面と内臓導体の距離を狭くすることにより、高周波電力がリング３７Ａ，３７Ｂの表面から放射され易くして、スパッタ効果を高めることができる。

【０１３４】上部電極カバー３０は、通常その周辺のみがボルト２５０で上部電極１２に固定される。ガス供給部３６からガス導入室３４、ガス拡散板３２、上部電極１２を介して上部電極カバー３０にガスが供給される。上部電極カバー３０に設けられた孔は、孔中の異常放電を生成し難くするため、０．３～１mm径の細孔になっており、上部電極カバー３０上部のガス圧は１気圧の数分の１から１／１０程度となる。例えば３００mm径の上部電極カバー３０に対して、全体として１００Ｋｇ程度以上の力が加わる。このため上部電極カバー３０が上部電極１２に対して凸状になり中央部付近では数百ミクロン以上の隙間を生じる。

【０１３５】この場合、高周波源１６の周波数が３０ＭＨｚ程度以上高くなると、上部電極カバー３０の横方向抵抗が無視出来なくなり、特に中央部付近のプラズマ密度が低下する現象が出る。これを改善するには、上部電極カバー３０を周辺以外の中心寄りで上部電極１２に固定すれば良い。図１４の例では、ＳｉＣやカーボン等の半導体もしくはアルミナ等の絶縁体のボルト２５１で、上部電極カバー３０の中心寄りの数ケ所を上部電極１２に固定し、上部電極１２側から印加される高周波の分布を一様にしている。

【０１３６】なお、上部電極カバー３０の少なくとも中心寄り部分を上部電極１２に固定する方法は、何ら上記ボルト２５１に限定されるものでなく、接着作用のある物質で上部電極カバー３０と上部電極１２とを全面でもしくは少なくとも中心寄りの部分で接着してもよい。

【０１３７】図１４の実施例において、処理の対象物である試料４０は、下部電極１５の上に載置され、静電チャック２０、すなわち直流電源２３による正電荷とプラズマから供給される負電荷により静電吸着膜２２の両端間に生じるクーロン力により吸着される。

【０１３８】この装置の作用は、図１に示した２電極型のプラズマエッチング装置と同様であり、エッチング処理を行う場合、処理を行なうべき試料４０を試料台１５に載置し、静電力で保持し、ガス供給系３６から処理室１０に処理ガスを所定の流量で導入しながら、他方真空ポンプ１８により真空排気することにより、処理室１０の圧力を試料の処理圧力、０．５～４．０Ｐａに減圧排気する。次に、高周波電源１６をオンとし、両電極１２，１５間に２０MHｚ～５００MHｚ、好ましくは３０MHｚ～１００MHｚの高周波電圧を印加してプラズマを発生させる。他方、下部電極１５に、パルスバイアス電源１７から２０Ｖ～１０００Ｖ、周期が０．１μs～１０μs好ましくは０．２μs～５μsの正のパルスバイアス電圧を印加し、処理室１０内のプラズマを制御して試料４０にエッチング処理を行う。

【０１３９】このようなパルスバイアス電圧の印加によって、プラズマ中のイオンもしくはイオン及び及び電子を試料に加速、垂直入射させることにより、高精度の形状制御あるいは選択比制御を行う。パルスバイアス電源１７及び静電吸着膜２２に必要な特性は図１の実施例と同様であり、詳細は省略する。

【０１４０】次に、図１５ないし図１７により本発明の他の実施例を説明する。この実施例は、図１に示した２電極型のプラズマエッチング装置と同様な構成であるが、磁場形成手段２００の構成が異なる。磁場形成手段２００のコア２０１は、偏心しており、試料４０の中心位置に相当する軸を中心にして、モータ２０４により駆動されて毎分数ないし数十回転の速度で回転するように構成されている。なお、コア２０１は接地されている。試料の全面を高精度にプラズマ処理するためには、試料の中央部付近に比べ、試料の周辺部ないしはその外側付近のプラズマの生成が高まる様に、電子のサイクロトロン共鳴効果を中央に比べ、周辺部ないしはその外側で大きくするのがよい。しかし、図１の実施例の場合、図６に示したように、試料の中心付近ではＥＣＲ領域が無く、中心付近でプラズマ密度が低くなり過ぎる場合が出てくる。

【０１４１】図１５の実施例では、磁場形成手段２００の偏心したコア２０１が回転することによって磁場の分布が変化し、試料の中心付近では時刻ｔ＝０，ｔ＝T_0では、ＥＣＲ領域が試料面から低い位置に形成され、時刻ｔ＝１／２T_0では試料面から高い位置に形成される。コア２０１が毎分数ないし数十回転の速度で回転する結果、図１７に示すように、両電極の中間部における試料面に平行な方向の磁場強度の平均値が、回転による時間平均化によりほぼ同じ値になる。すなわち、ＥＣＲ

領域が試料の周辺部を除き試料面からほぼ同じ高さの位置に形成される。
【０１４２】なお、図１５のコア２０１部で一点鎖線で示したように、偏心した中央部のコアに近い側の磁気回路を構成するコアはその厚さを薄く、遠い側の磁気回路を構成するコアはその厚さを厚くすれば、磁場強度の均一性はさらに向上する。
【０１４３】次に、図１８ないし図１９により本発明の他の実施例を説明する。この実施例は、図１５に示した２電極型のプラズマエッチング装置と同様な構成であるが、磁場形成手段２００の構成が異なる。磁場形成手段２００のコア２０１は、処理室の中央に対応する位置に凹面のエッジ２０１Ａを有し、処理室の側方位置他のエッジ２０１Ｂを有している。凹面のエッジ２０１Ａの作用により、磁束Ｂは傾斜した方向成分を有する。その結果、磁場の分布が変化し、図１９に示したように、試料面に平行な成分の磁場強度が図１の実施例の場合に比べて、より均一化される。
【０１４４】次に、図２０により本発明の他の実施例を説明する。この実施例は、図１５に示した２電極型のプラズマエッチング装置と同様な構成であるが、磁場形成手段２００の構成が異なる。磁場形成手段２００のコア２０１は固定式であり、処理室の中央に対応する位置に配置されたコア２０５と共に磁気回路を構成する。コア２０５は、絶縁体２０３と共に、エッジ２０１Ａの中心を通る軸の廻りを回転する。このような構成により、図１５の実施例と同様にして、試料の中心付近におけるＥＣＲ領域の平均的な位置が、試料面からほぼ同じ位置に形成される。すなわち、ＥＣＲ領域が試料の全面に亘り試料面からほぼ同じ高さの位置に形成される。
【０１４５】次に、図２１ないし図２２により本発明の他の実施例になる２電極型のプラズマエッチング装置を説明する。この実施例では、磁場形成手段２００が、処理室１０の周囲に２対のコイル２１０，２２０を備えており、各対のコイルに置ける磁界の向きを矢印１，２，３，４のように順次切り替えることにより、回転磁界を形成するように構成されている。コイル２１０，２２０の中心位置Ｏ－Ｏは、両電極１２，１５の中間よりも上部電極１２側に位置している。これによって、試料４０上の磁場強度を３０ガウス以下、好ましくは１５ガウス以下になるように構成している。コイル２１０，２２０の位置、外径を適宜選定することによって、試料の周辺部ないしはその外側付近のプラズマの生成がより高まる様に、磁場の強度分布を調整することができる。
【０１４６】次に、図２３、図２４により、本発明の他の実施例になる２電極型のプラズマエッチング装置を説明する。この実施例では、磁場形成手段２００として、円形の処理室１０の周囲に沿って水平面内で円弧状に配置された一対のコイル２１０’を備えている。この一対のコイル２１０’に流れる電流を制御して、図２３に矢印（１）、（２）で示したように、一定周期毎に磁場の極性を変化させる。
【０１４７】図２４に破線で示すように、磁束Ｂは、垂直面内では処理室中心部で拡がるため、処理室中心部の磁場強度は低下する。しかし、一対のコイル２１０’は、処理室に沿ってカーブしているため、水平面内では、処理室中心部に磁束Ｂが集まる様になっている。そのため、処理室中心部の磁場の強さを、図２２の実施例に比べて、高めることができる。すなわち、図２３の実施例では、図２２の実施例に比べて、処理室中心部における磁場強度の低下を抑制することができ、試料台の試料載置面における磁場強度の均一性を向上させることができる。
【０１４８】また、一定周期毎に磁場の極性を変化させることによって、Ｅ×Ｂのドリフト効果を少なくしている。
【０１４９】なお、磁場形成手段２００として、図２２の実施例と同様な、２対のコイルを採用しても良い。
【０１５０】また、磁場形成手段２００として、円弧状コイル２１０’に代えて、図２５に示すように、円形の処理室１０の周囲に沿って配置された複数の直線コイル部分の組み合わせになる、凸型のコイル２１０’としても良い。この場合も、水平面内では、処理室中心部に磁束Ｂが集まる様になり、図２３の実施例と同じ効果が得られる。
【０１５１】さらに、図２６の実施例のように、１対のコイルの中心軸を、処理室中心部で試料面に近づくように、垂直面内で傾斜させて配置しても良い。この実施例によれば、処理室中心部の磁場強度を上げ、処理室周辺部の磁場強度を下げることができるので、試料台の試料載置面における磁場強度の均一性を向上させることができる。なお磁場強度の均一化のためには、コイルの中心軸の傾斜角度θを、５度乃至２５度の範囲とするのが良い。
【０１５２】また、図２７に示すように、一対のコイル２１０Ａの近傍に、コイル２１０Ｂを設置し、２組のコイルの電流を制御することにより、ＥＣＲ共鳴位置と共に、ＥＣＲ共鳴位置付近での磁場の勾配を変化させ、ＥＣＲ共鳴領域の幅を変化させることもできる。ＥＣＲ共鳴領域の幅をプロセス毎に最適化することにより、各プロセスに適したイオン／ラジカル比を得ることが可能となる。
【０１５３】なお、以上述べた、図２３乃至図２７の実施例を、必要に応じて適宜組み合わせることにより、磁場強度分布の均一性と制御特性を更に向上させることが出来る。
【０１５４】次に、図２８ないし図２９により本発明の他の実施例になる２電極型のプラズマエッチング装置を説明する。この実施例では、処理室壁の一部が導電体で構成されると共に接地されている。一方、磁場形成手段

２００が、処理室１０の周囲及び上部にコイル２３０，２４０を備えている。コイル２３０で形成される磁束Ｂの向きと、コイル２３０で形成される磁束Ｂ’の向きは、矢印で示すように、処理室１０の中心部では互いに打消合い、処理室１０の周辺およ外側では互いに重畳するように構成されている。その結果、試料面上の磁場の強度分布は図２９のようになる。しかも、試料４０の載置面部分では、上部電極１２と下部電極１５の間の電界成分の向きと磁界成分の向きは平行である。一方、試料４０の載置面の外側部分では、上部電極１２の周辺部ないしは上部電極１２と処理室壁との部分で、横方向の電界成分と直交する縦方向の磁界成分が生じる。

【０１５５】従って、図２８の実施例によれは、試料の中心付近における電子のサイクロトロン共鳴効果を下げ、試料の周辺部ないしはその外側付近のプラズマの生成を高めることができる。このようにして、試料の周辺部ないしはその外側付近のプラズマの生成をより高めることにより、プラズマ密度分布を均一化することができる。

【０１５６】次に、図３０により本発明の他の実施例を説明する。この実施例は、図１に示した２電極型のプラズマエッチング装置において、高周波電源１６から上部電極１２に印加する高周波電力ｆ1では、充分なイオンエネルギーが得られない場合に、低周波電源１６３から上部電極１２に、例えば1ＭＨｚ程度以下の高周波ｆ３をバイアスとして印加することによって、イオンエネルギーを１００～２００Ｖ程度増大させるものである。なお、１６４，１６５はフィルターである。

【０１５７】次に、図３１により、無磁場型の２電極型のプラズマエッチング装置における、本発明の実施例を説明する。

【０１５８】前にも述べたように、試料の微細加工性を向上させるには、プラズマ発生用高周波電源１６としてより高い周波数のものを用い、低ガス圧領域での放電の安定化を計るのがよい。本発明の実施例では、処理室１０における試料の処理圧力を０．５～４．０Ｐａとしている。処理室１０内のガス圧力を４０mTorr以下の低圧にすることにより、シース中でのイオンの衝突が少なくなるので、試料４０の処理に際して、イオンの方向性が増し垂直な微細加工が可能になった。なお、5mTorr以下では、同じ処理速度を得るには、排気装置や高周波電源が大型化すると共に、電子温度の上昇による必要以上の解離が生じ、特性が劣化する傾向がある。

【０１５９】一般に、一対の２電極を用いたプラズマ発生用の電源の周波数と安定的に放電が行われる最低のガス圧力との間には、図３２に示すように、電源の周波数が高くなるほど、電極間距離が大きくなるほど、安定放電最低ガス圧が低下するという関係がある。周囲の壁や放電閉込めリング３７へのデポ等の悪影響を避け、上部電極カバー３０やサセプタカバー３９や試料中のレジスト等によるフッ素や酸素を除去する効果を有効に機能させるために、最高ガス圧４０mTorr時の平均自由工程の２５倍以下に対応して、電極間距離を５０㎜程度以下とするのが望ましい。また、電極間距離として、最高ガス圧（４０mTorr）時の平均自由工程の２～４倍（４㎜～８㎜）程度以上でないと、安定な放電が困難となる。

【０１６０】図３１に示した実施例では、プラズマ発生用高周波電源１６として、２０MHｚ～５００MHｚ、望ましくは３０MHｚ～２００MHｚの高周波電力を用いるため、処理室内のガス圧力を、０．５～４．０Ｐａの低圧にしても、安定したプラズマが得られ、微細加工性を向上させることができる。また、このような高周波電力を用いることによりガスプラズマの解離が良くなり、試料加工時の選択比制御が良くなる。

【０１６１】以上述べた本発明の実施例において、パルスバイアス電源の出力とプラズマ発生用電源の出力との間に干渉が生ずる可能性も考えられる。そこで、以下、この対策についてのべる。

【０１６２】まず、パルス幅：T_1，パルス周期：T_0で無限大の立上り／立下り速度をもつ理想的な矩形パルスにおいては、図３３に示す様に、$f \leqq 3f_0$（$f_0 = (1/T_1)$）の周波数範囲に７０～８０％程度の電力が含まれる。実際に印加される波形は、立上り／立下り速度が有限となるため、電力の収束性は更に改善され、$f \leqq 3f_0$の周波数範囲に９０％程度以上の電力が含まれる様にできる。

【０１６３】$3f_0$ なる高い周波数成分をもつパルスバイアスを試料面内に均一に印加される様にするためには、試料にほぼ平行な対向電極を設け、次式数３で求まる$3f_0$に対して、$f \leqq 3f_0$ なる範囲の周波数成分を接地することが望ましい。

【０１６４】

【数３】

$$T_1=0.2\,\mu s\text{とすると}\quad 3f_0=3\cdot\frac{10^6}{0.2}=15\mathrm{MHz}$$

$$T_1=0.1\,\mu s\text{とすると}\quad 3f_0=30\mathrm{MHz} \qquad \cdots\cdots \text{数３}$$

【０１６５】図３１に示した実施例は、上記パルスバイアス電源出力とプラズマ発生用電源出力との干渉の対策を行っている。すなわち、このプラズマエッチング装置において、試料４０と対向する上部電極１２には、プラズマ発生用高周波電源１６が接続される。この上部電極１２をパルスバイアスの接地レベルにするには、プラズ

マ発生用高周波電源１６の周波数f_1を上記の３f_0より大きくし、かつ、$f=f_1$付近でのインピーダンスが大きく、他の周波数ではインピーダンスが低い、バンドエリミネータ１４１を上部電極１２と接地レベルとの間に接続する。

【０１６６】一方、$f=f_1$付近でのインピーダンスが低く、他の周波数はインピーダンスが高いバンドパスフィルタ１４２を、試料台１５と接地レベル間に設置する。このような構成を用いれば、パルスバイアス電源１７の出力とプラズマ発生用電源１６出力との間の干渉を、問題のないレベルに抑え、試料４０に良好なバイアスを加えることができる。

【０１６７】図３４は、本発明を外部エネルギー供給放電方式のうち誘導結合型放電方式でかつ、無磁場タイプのプラズマエッチング装置へ適用した例である。５２は平面コイル、５４は平面コイルに１０MHｚ～２５０MHｚの高周波電圧を印加する高周波電源である。誘導結合型放電方式は図１０に示した方式に比べ、低い周波数でかつ低圧での安定なプラズマ発生が可能になる。逆に、解離が進みやすくなるため、図１で示したように、高周波電源１の出力を高周波電源変調信号源１６１により変調し、不必要な解離を防ぐことが出来る。真空容器としての処理室１０は、静電吸着膜２２の上に試料４０が載置される試料台１５を備えている。

【０１６８】エッチング処理を行う場合、処理を行なうべき試料４０を試料台１５に載置し、静電力で保持し、ガス供給系（図示せず）から処理室１０に処理ガスを所定の流量で導入しながら、他方真空ポンプにより真空排気することにより、処理室１０の圧力を０．５～４．０Ｐａに減圧排気する。次に、高周波電源５４に１３．５６MHｚの高周波電圧を加えて処理室１０にプラズマを発生させる。このプラズマを用いて試料４０をエッチング処理する。他方、エッチング時には、下部電極１５に、周期が０．１μs～１０μs好ましくは０．２μs～５μsのパルスバイアス電圧を印加する。パルスバイアス電圧の振幅は、膜種により範囲が異なることは図１の実施例で述べたとおりである。このパルスバイアス電圧の印加によって、プラズマ中のイオンを試料に加速、垂直入射させることにより、高精度の形状制御あるいは選択比制御を行う。これにより、試料のレジストマスクパターンが極微細なものであっても、高精度のエッチング処理を行うことができる。

【０１６９】また、図３５に示すように、誘導結合型放電方式無磁場タイプのプラズマエッチング装置において、誘導電高周波出力の処理室１０側に、隙間を有するファラデーシールド板５３と、０．５mm～５mmの薄いシールド板保護用絶縁板５４を設置し、そのファラデーシールド板を接地してもよい。ファラデーシールド板５３の設置によって、コイルとプラズマ間の容量成分が少なくなり、図３４におけるコイル５２下の石英板やシールド板保護用絶縁板５４を叩くイオンのエネルギーを低下することが出来、石英板や絶縁板の損傷を少なくすると共に、プラズマ中への異物の混入を防ぐことが出来る。

【０１７０】また、ファラデーシールド板５３は、パルスバイアス電源１７の接地電極の役目も兼ねるため、試料４０とファラデーシールド板５３との間に均一にパルスバイアスを印加することが出来る。この場合、上部電極や試料台１５に設置するフィルタは不要である。

【０１７１】図３６は、本発明をマイクロ波プラズマ処理装置に適用した装置の一部を縦断面した正面図である。静電吸着膜２２の上に試料４０が載置される試料台１５としての下部電極１５には、パルスバイアス電源１７及び直流電源１３が接続されている。４１はマイクロ波の発振源としてのマグネトロン、４２はマイクロ波の導波管であり、４３は、処理室１０を真空封止しマイクロ波を処理室１０に供給するための石英板である。４７は磁場を供給する第一のソレノイドコイル、４８は磁場を供給する第二のソレノイドコイルである。４９は処理ガス供給系であり、処理室１０内にエッチング、成膜等の処理を行なう処理ガスを供給する。また、処理室１０は、真空ポンプ（図示せず）により真空排気される。パルスバイアス電源１７及び静電チャック２０に必要な特性は図１の実施例と同様であり、詳細は省略する。

【０１７２】エッチング処理を行う場合、処理を行なうべき試料４０を試料台１５に載置し、静電力で保持し、ガス供給系４９から処理室１０に処理ガスを所定の流量で導入しながら、他方真空ポンプにより真空排気することにより、処理室１０の圧力を０．５～４．０Ｐａに減圧排気する。次に、マグネトロン４１及び第一、第二のソレノイドコイル４７、４８をオンとし、マグネトロン４１で発生したマイクロ波を導波管４２から処理室１０に導びいて、プラズマを発生させる。このプラズマを用いて試料４０にエッチング処理を行う。他方、エッチング時には、下部電極１５に、周期が０．１μs～１０μs好ましくは０．２μs～５μsのパルスバイアス電圧を印加する。

【０１７３】このようなパルスバイアス電圧の印加によって、プラズマ中のイオンを試料に加速して、垂直に入射させることにより、高精度の形状制御あるいは選択比制御を行う。これにより、試料のレジストマスクパターンが極微細なものであっても、垂直入射によりマスクパターンに対応した高精度のエッチング処理が行える。

【０１７４】なお、図１以下に示した本発明のプラズマエッチング装置において、静電吸着回路の直流電圧とパルスバイアス電源回路のパルス電圧を重畳して生成し、回路を共通に構成することもできる。また、静電吸着回路とパルスバイアス電源回路を別な電極に分離して設け、パルスバイアスが静電吸着に影響を及ぼさないようにすることもできる。

【０１７５】図１に示したプラズマエッチング装置の実

施例における静電吸着回路に代えて、他の吸着手段、例えば真空吸着手段を用いることもできる。

【０１７６】以上述べた本発明の静電吸着回路とパルスバイアス電圧印加回路を備えたプラズマ処理装置は、エッチングガスに代えてＣＶＤガスを導入する等の変更を加えることにより、以上述べたエッチング処理に限らずＣＶＤ装置等のプラズマ処理装置にも適用できる。

【０１７７】次に、図３７に示した本発明の他の実施例により、従来の欠点を改善し、イオンとラジカル生成の量と質を制御し、極微細なプラズマ処理を可能とするプラズマエッチング装置の他の実施例について述べる。

【０１７８】すなわち、試料を設置している真空処理室の上流側で真空処理室とは別の場所に第一のプラズマ生成を行う場所を設定し、そこで生成した準安定原子を真空処理室に注入し、真空処理室にて第二のプラズマを生成する構成としている。図１に示したプラズマエッチング装置に加えて、イオン・ラジカル源用ガス供給部６０と、準安定原子発生用プラズマ発生室６２を備えている。また上部電極１２には、準安定原子を含むガスを真空処理室に導入するルートのほかに、イオン・ラジカル源用ガス供給部に繋がっている導入ルートを設けている。

【０１７９】この実施例の特徴は、次の通りである。

ィ準安定原子発生用ガス供給部３６から供給されたガスを準安定原子発生用プラズマ発生室６２にて高周波電力を印加してプラズマ化し、あらかじめ所望の準安定原子を所望量発生させ処理室１０に流入させる。準安定原子発生用プラズマ発生室６２は、効率良く準安定原子を発生させるために、室内の圧力は、数百mTorr～数十Torrの高い圧力に設定する。

【０１８０】ィ他方、イオン・ラジカル源用ガス供給部６０からのガスを処理室１０に流入させる。

【０１８１】ィプラズマ発生用電源１６で比較的低電力の高周波を出力し、処理室１０にプラズマを発生させる。準安定原子の注入により、５ｅＶ程度以下の低エネルギーの電子でもイオンを効率良く生成させることができるため、低電子温度（６ｅＶ程度以下、好ましくは４ｅＶ程度以下）で、かつ１５ｅＶ程度以上の高エネルギー電子が大幅に少ないプラズマが得られる。このため、ラジカル源用ガスは過剰な解離を生じさせることなく必要な量と質を確保出来る。一方イオンの量は、準安定原子発生用プラズマ発生室６２にて発生する準安定原子の量と、イオン・ラジカル源用ガス供給部６０からのイオン源用ガスにて制御することができる。

【０１８２】このようにしてイオンとラジカル生成の質や量を制御できる様になるため、極微細なプラズマ処理においても良好な性能が得られる。ラジカル源用ガスとしては、ＣＨＦ３、ＣＨ２Ｆ２，Ｃ４Ｆ８あるいはＣＦ４などのフルオロカーボンガスに、必要に応じてＣ，Ｈを含むガス（Ｃ２Ｈ４，ＣＨ４，ＣＨ３ＯＨなど）を混ぜてもちいる。準安定原子発生用ガスとしては、１種類ないしは２種類の希ガスをベースにしたものを用いる。イオン源用ガスとしては、下記の性質を持つ希ガス等を用いることにより、効率良くイオンを生成できる。

【０１８３】前記準安定原子のエネルギー準位に対し、イオン源用ガスの電離準位が低いもの、もしくは、イオン源用ガスの電離準位の方が高いが、その差が小さい（５ｅＶ程度以下）ものが用いられる。

【０１８４】尚、性能的には低下するがイオン源用ガスとして特に追加せず、上記準安定原子発生用ガスやラジカル源用ガスで代用することもできる。

【０１８５】次に、図３８にイオンとラジカル生成の質や量を制御する本発明の他の実施例を示す。図３７と基本的考えは、同じであるが、図３７において、準安定原子発生用プラズマ室６２と真空処理室１０との間の距離が長く、この間での準安定原子の減衰が大きい場合の対策として実施する例である。４１はマイクロ波の発振源としてのマグネトロン、４２はマイクロ波の導波管であり、４３は第一のプラズマ生成室４５を真空封じして、マイクロ波を通過させるための石英板であり、４４はガス分散用の石英板である。第一のプラズマ生成室４５では、数１００ｍＴｏｒｒから数１０Ｔｏｒｒのガス圧で前記マイクロ波によりプラズマを発生させ、準安定原子を発生させる。

【０１８６】図３８では、図３７に比較し準安定原子の発生場所と真空処理室間の距離を短く出来るため、高い密度で準安定原子を真空処理室に注入することができ、真空処理室１０におけるイオンの量を増加できる。処理室１０は５～５０ｍTorrの圧力に保ち、２０ＭＨｚ以上の高周波電源１６により、５ｅＶ好ましくは３ｅＶ以下で１０の１０乗から１１乗台／ｃｍ３の高密度低電子温度プラズマを発生させ、解離エネルギーとして８ｅＶ以上を必要とするＣＦ２の解離を避けつつ、イオン源用ガスの電離を進行させる。この結果、試料４０の表面上では、バイアス電源１７により数１００Ｖで加速されたイオンの入射でアシストされた下記反応が主に進行する。

ＳｉＯ２＋２ＣＦ２　→　ＳｉＦ４　↑＋２ＣＯ　↑

なお、下地材料となるＳｉやＳｉＮは、ＣＦ２ではエッチングされないため、高選択比の酸化膜エッチングが可能となった。

【０１８７】また、ＣＦ２の一部解離によるＦの増加は、シリコン、カーボンもしくはＳｉＣ等からなる上部電極カバー３０により減少させている。

【０１８８】上で述べたように、ラジカル源用ガスとイオン源用ガスとを調節することにより、処理室１０内でのイオンとラジカルとの比率をほぼ独立に制御でき、試料４０の表面での反応を所望のものにコントロールすることが容易になった。

【０１８９】本発明の、静電吸着回路とパルスバイアス

電圧印加回路を備えたプラズマ処理装置は、エッチングガスに代えてＣＶＤガスを導入する等の変更を加えることにより、以上述べたエッチング処理に限らずＣＶＤ装置等のプラズマ処理装置にも適用できる。

【０１９０】次に、図３９にイオンとラジカルとを独立に制御する本発明の他の実施例を示す。図３９において、ＣＨＦ３、ＣＨ２Ｆ２，Ｃ４Ｆ８あるいはＣＦ４などのフルオロカーボンガスに、必要に応じてＣ，Ｈを含むガス（Ｃ２Ｈ４，ＣＨ３ＯＨなど）を混ぜ、図３９のＡなる部分よりバルブ７０を経由してラジカル発生用プラズマ発生室６２に入れる。

【０１９１】ラジカル発生用プラズマ発生室６２では、数ＭＨｚないしは数１０ＭＨｚのＲＦ電源６３の出力をコイル６５に印加し、数１００ｍＴｏｒｒから数１０Ｔｏｒｒのガス圧でプラズマを発生させ、主にＣＦ２ラジカルを発生させる。同時に発生するＣＦ３やＦはＨ成分により減少させる。

【０１９２】なお、ラジカル発生用プラズマ発生室６２でＣＦやＯ等の成分を大幅に減少させることは困難なため、この後に不要成分除去室６５を設ける。ここでは、カーボンやＳｉを含む材質（カーボン、Ｓｉ，ＳｉＣ等）の内壁を設置し、不要な成分を減少、あるいは悪影響の少ない別のガスに変換させる。不要成分除去室６５の出口は、バルブ７１に接続し、ＣＦ２が主成分のガス組成を供給する。

【０１９３】なお、バルブ７０とバルブ７１との間は、デポ物等の堆積物が多く蓄積するため、比較的短期間で清掃や交換が必要である。このため、大気開放と交換とを容易にすると共に、再立ち上げ時の真空立ちあげ時間の短縮のため、バルブ７２を経由して排気装置７４に接続している。なお排気装置７４は、処理室１０用排気装置等と兼用してもよい。

【０１９４】またイオン源用ガス（アルゴンガスやキセノンガス等の希ガス）Ｂはバルブ７３を経由し、前記のバルブ７１の出口と繋ぎ処理室に供給する。

【０１９５】処理室１０は５～４０ｍＴの圧力に保ち、変調を施した２０ＭＨｚ以上の高周波電源１６により、５ｅＶ好ましくは３ｅＶ以下で１０の１０乗から１１乗台／ｃｍ３の高密度低電子温度プラズマを発生させ、解離エネルギーとして８ｅＶ以上を必要とするＣＦ２の解離を避けつつ、イオン源用ガスの電離を進行させる。この結果、試料４０の表面上では、バイアス電源１７により数１００Ｖで加速されたイオンの入射でアシストされた下記反応が主に進行する。

ＳｉＯ２＋２ＣＦ２　→　ＳｉＦ４　↑＋２ＣＯ　↑

なお、下地材料となるＳｉやＳｉＮは、ＣＦ２ではエッチングされないため、高選択比の酸化膜エッチングが可能となった。

【０１９６】また、ＣＦ２の一部解離によるＦの増加は、シリコン、カーボンもしくはＳｉＣ等からなる上部電極カバー３０により減少させている。

【０１９７】上で述べたように、ラジカル源用ガスＡとイオン源用ガスＢとを調節することにより、処理室１０内でのイオンとラジカルとの比率をほぼ独立に制御でき、試料４０の表面での反応を所望のものにコントロールすることが容易になった。また、不必要なデポ成分等は、不要成分除去室６５で排除し、処理室１０には極力持ち込まないようにしているため、処理室１０内のデポは大幅に低減され、処理室１０を大気に開放して行う清掃の頻度も大幅に低減できた。

【０１９８】次に、図４０にイオンとラジカルとを独立に制御する他の実施例を示す。酸化ヘキサフルオロプロピレンガス（ＣＦ３ＣＦＯＣＦ２，以下ＨＦＰＯと略す）をＡより、バルブ７０を経由して加熱パイプ部６６に通し、不要成分除去室６５とバルブ７１を経由し、イオン源ガスＢと混合し、処理室１０のほうに送る。加熱パイプ部６６では、８００℃～１０００℃にＨＦＰＯを加熱し下記の熱分解によりＣＦ２を生成する。

ＣＦ３ＣＦＯＣＦ２　→　ＣＦ２＋ＣＦ３ＣＦＯ

ＣＦ３ＣＦＯは比較的安定な物質で分解しにくいが、一部分解し不要なＯやＦを発生するため、加熱パイプ部６６の後に不要成分除去室６５をもうけ不要成分を除去、あるいは悪影響のでない物質に変換している。一部のＣＦ３ＣＦＯＣＦ２は分解しないで処理室１０に流入するが、５ｅＶ以下の低電子温度のプラズマでは解離しないため問題とはならない。

【０１９９】なお、バルブ７２、排気装置７４の用い方ならびに処理室１０内での反応は、図３９の場合と同じである。

【０２００】本発明の、静電吸着回路とパルスバイアス電圧印加回路を備えたプラズマ処理装置は、エッチングガスに代えてＣＶＤガスを導入する等の変更を加えることにより、以上述べたエッチング処理に限らずＣＶＤ装置等のプラズマ処理装置にも適用できる。

【０２０１】

【発明の効果】本発明によれば、φ３００ｍｍ以上の大口径の試料について微細パターンの精密な加工が容易で、また、微細加工時の選択比も向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。また、大口径の試料の全面にわたって均一かつ高速な処理、特に酸化膜処理を施すことができるプラズマ処理装置およびその処理方法を提供することができる。

【０２０２】本発明によれば、さらに、試料中の絶縁膜（例えばＳｉＯ２，ＳｉＮ，ＢＰＳＧ等）に対するプラズマ処理の選択性等を向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。

【０２０３】また、制御性が良くかつ狭いイオンエネルギー分布を得て、プラズマ処理の選択性等を向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。

【０２０４】また、静電吸着用誘電体層を有する試料台を使用する場合において、制御性良く、狭いイオンエネルギー分布を得て、プラズマ処理の選択性等を向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。

【０２０５】また、イオンとラジカルの量や質を独立に制御することにより、プラズマ処理装置の処理室内の圧力を低くして、微細パターンの精密な加工が容易で、また、微細加工時の選択比も向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。

【０２０６】さらにまた、イオンとラジカルの量や質を独立に制御することにより、試料中の絶縁膜（例えばＳｉO2，ＳｉＮ，ＢＰＳＧ等）に対するプラズマ処理の選択性等を向上させたプラズマ処理装置及びプラズマ処理方法を提供することができる。

【図面の簡単な説明】

【図１】本発明の一実施例になる、２電極型のプラズマエッチング装置の縦断面図である。

【図２】電子のサイクロトロン共鳴を生じる磁場を加えた状態で、プラズマを発生させる高周波電源の周波数を変化させたときの、プラズマ密度の変化の一例を示す図である。

【図３】サイクロトロン共鳴時と無共鳴時とに電子が高周波電界から得るエネルギー利得ｋの状況を示す図である。

【図４】マグネトロン放電電極の上部電極を接地し、下部電極に磁界Ｂを与えると共に高周波電力を印加した時の、磁界強度と、試料に誘起されるイオン加速電圧VDC及び試料内の誘起電圧のバラツキΔＶの関係を示す図である。

【図５】図１のプラズマエッチング装置の磁界特性の説明図である。

【図６】図１のプラズマエッチング装置のＥＣＲ領域の説明図である。

【図７】本発明のパルスバイアス電源において使用する望ましい出力波形の例を示す図である。

【図８】パルスデューティ比：（T_1／T_0）は一定のままT_0 を変化させた時の試料表面の電位波形とイオンエネルギーの確率分布を示す図である。

【図９】パルスデューティ比を一定のまま、T_0 を変化させた時の試料表面の電位波形とイオンエネルギーの確率分布を示す図である。

【図１０】パルスのオフ（T_0-T_1）期間と、静電吸着膜の両端間に生じる電圧の一周期中の最大電圧V_{CM} の関係を示す図である。

【図１１】パルスデューティ比と（V_{DC}／v_p ）の関係を示す図である。

【図１２】塩素ガスをプラズマ化した時のシリコンと酸化膜とのエッチングレートＥＳｉおよびＥＳｉO_2のイオンエネルギー依存性を示す図である。

【図１３】酸化膜のエッチングの例としてC_4F_8ガスをプラズマ化した時の、酸化膜とシリコンとのエチングレートＥＳｉO_2および、ＥＳｉのイオンエネルギー分布を示す図である。

【図１４】本発明の他の実施例になる２電極型のプラズマエッチング装置の縦断面図である。

【図１５】本発明の他の実施例になる２電極型のプラズマエッチング装置の縦断面図である。

【図１６】図１５プラズマエッチング装置の磁場分布特性の説明図である。

【図１７】図１５のプラズマエッチング装置のＥＣＲ領域の説明図である。

【図１８】本発明の他の実施例になるプラズマエッチング装置の縦断面図である。

【図１９】図１８のプラズマエッチング装置の磁場分布特性の説明図である。

【図２０】本発明の他の実施例になる、２電極型のプラズマエッチング装置の縦断面図である。

【図２１】本発明の他の実施例になる、２電極型のプラズマエッチング装置の縦断面図である。

【図２２】図２１のプラズマエッチング装置の磁場分布特性の説明図である。

【図２３】本発明の他の実施例になる２電極型のプラズマエッチング装置の要部横断面図である。

【図２４】図２３のプラズマエッチング装置の縦断面図である。

【図２５】磁場形成手段の他の実施例を示す図である。

【図２６】本発明の他の実施例になる、２電極型のプラズマエッチング装置の縦断面図である。

【図２７】本発明の他の実施例になる、２電極型のプラズマエッチング装置の縦断面図である。

【図２８】本発明の他の実施例になる、２電極型プラズマエッチング装置の縦断面図である。

【図２９】図２８のプラズマエッチング装置の磁場分布特性の説明図である。

【図３０】本発明の他の実施例になる、２電極型プラズマエッチング装置の縦断面図である。

【図３１】図１に示した２電極型プラズマエッチング装置を改良した他の実施例の縦断面図である。

【図３２】プラズマ発生用電源の周波数と安定放電最低ガス圧の関係を示す図である。

【図３３】パルスバイアス電源の周波数と累積電力の関係を示した図である。

【図３４】本発明を、外部エネルギー供給放電方式のうち、誘導結合型放電方式でかつ、無磁場タイプのプラズマエッチング装置へ適用した例の縦断面図である。

【図３５】本発明の他の実施例になる、プラズマエッチング装置の縦断面図である。

【図３６】本発明をマイクロ波プラズマ処理装置に適用した装置の一部を縦断面した正面図である。

【図３７】本発明の他の実施例になる、プラズマエッチング装置の縦断面図である。

【図３８】本発明の他の実施例になる、プラズマ処理装置の一部を縦断面した正面図である。

【図３９】本発明の他の実施例になる、イオンとラジカルを独立して制御可能な、２電極プラズマエッチング装置の縦断面図である。

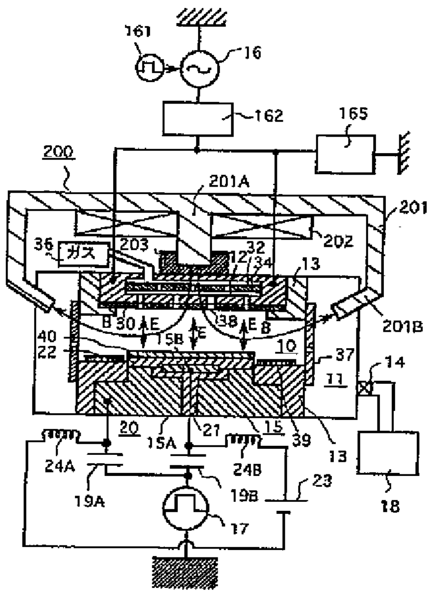
【図４０】本発明の他の実施例になる、イオンとラジカルを独立して制御可能な、２電極プラズマエッチング装置の部分詳細図である。

【符号の説明】

１０…処理室、１２…上部電極、１５…下部電極、１６…高周波電源、１７…パルスバイアス電源、１８…真空ポンプ、２０…静電チャック、２２…静電吸着膜、２３…直流電源、３０…上部電極カバー、３２…ガス拡散板３２、３６…ガス供給部３、４０…試料、１６１…高周波電源変調信号源、２００…磁場形成手段２００、２０１…コア、２０２…電磁コイル、２０３…絶縁体

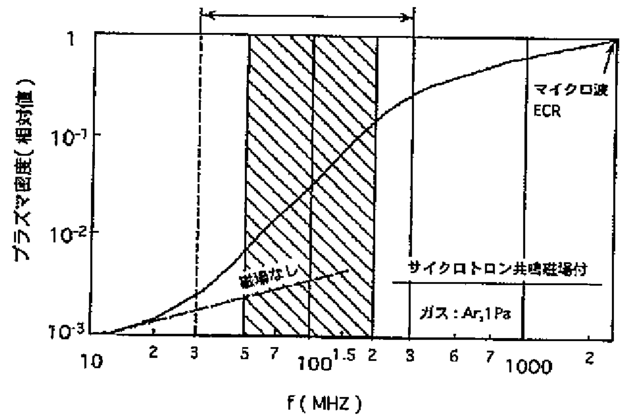
【図１】

図１



【図２】

図２



【図３】

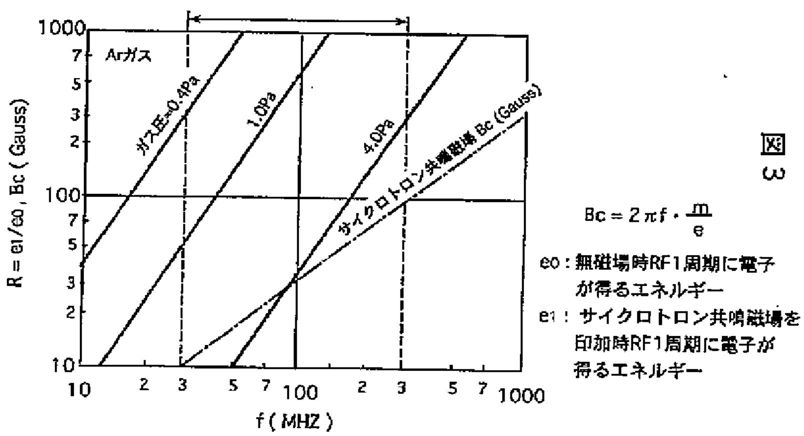
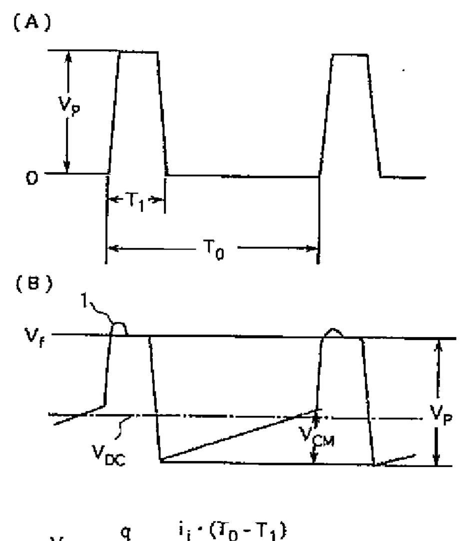


図３

【図７】

図７



$$V_{CM} = \frac{q}{c} = \frac{i_i \cdot (T_0 - T_1)}{(\varepsilon_\gamma \varepsilon_0 / d) \times K}$$

ii：イオン電流密度

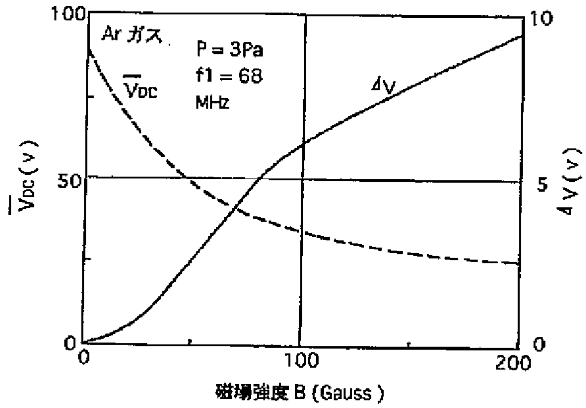
εr：静電吸着膜の比誘電率

d：静電吸着膜の膜圧

k：静電吸着膜の電極被覆率

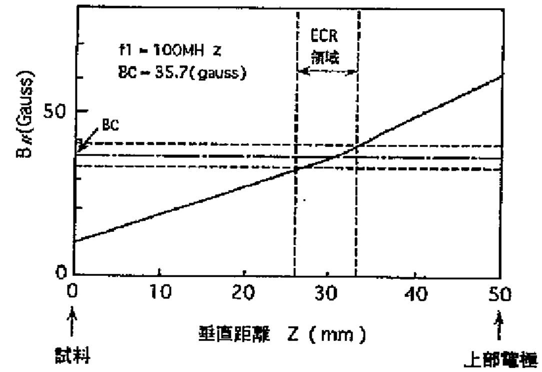
【図４】

図 4



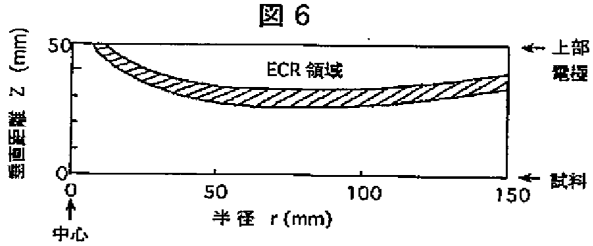
【図５】

図 5



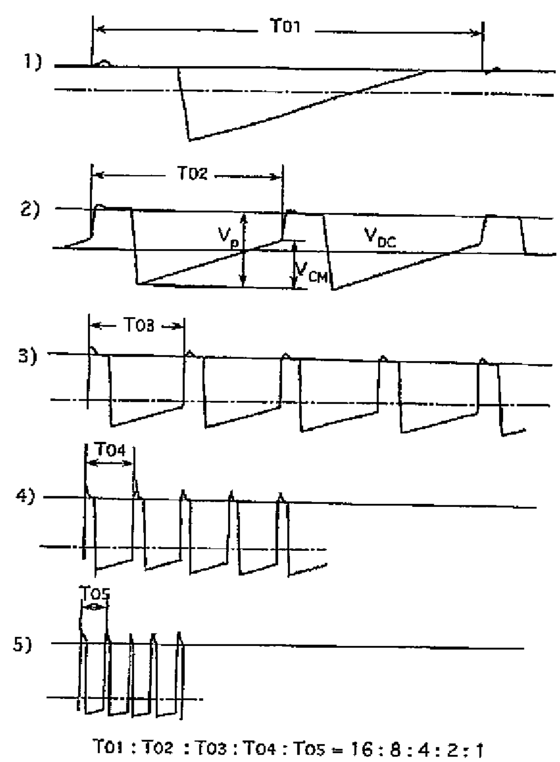
【図６】

図 6



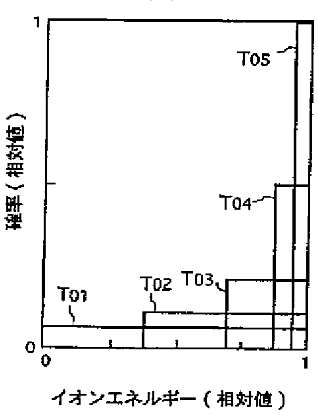
【図８】

図 8



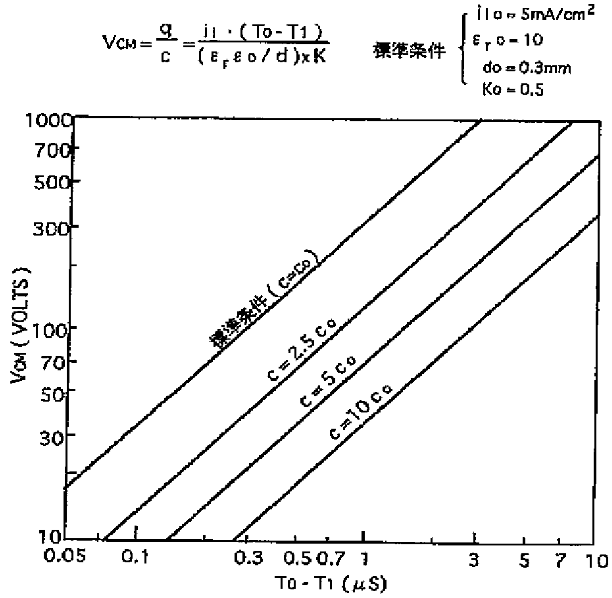
【図９】

図 9



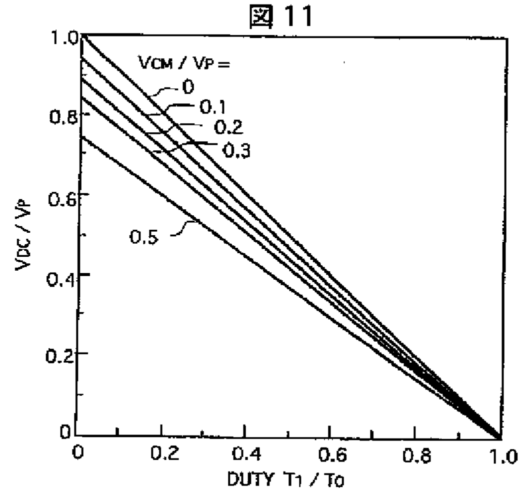
【図１０】

図 10



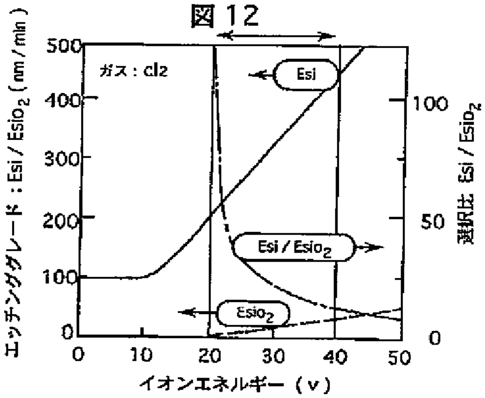
【図１１】

図 11



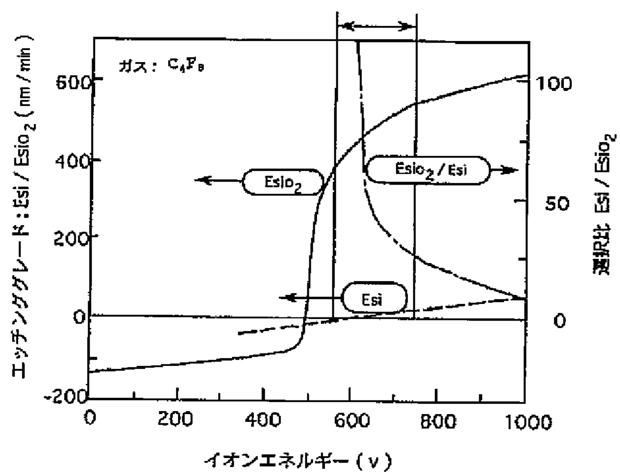
【図１２】

図 12



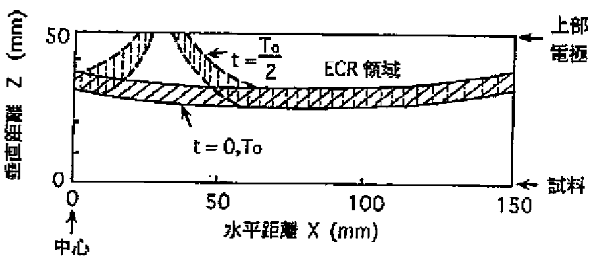
【図１３】

図 13



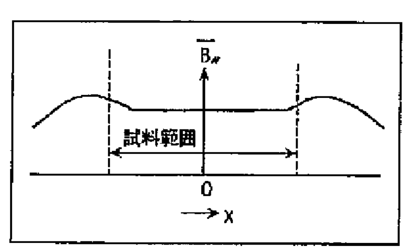
【図１６】

図 16



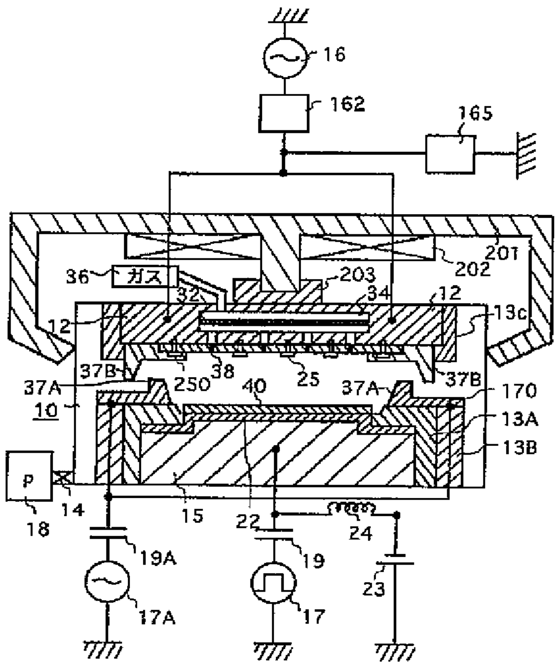
【図１７】

図 17



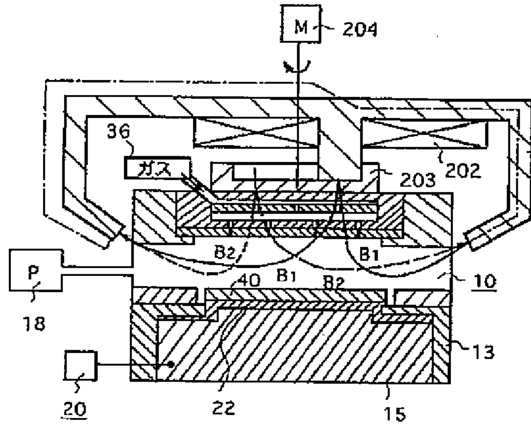
【図１４】

図 14



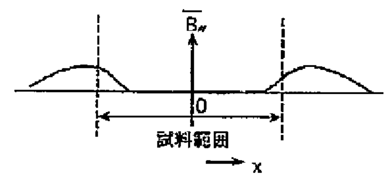
【図１５】

図 15



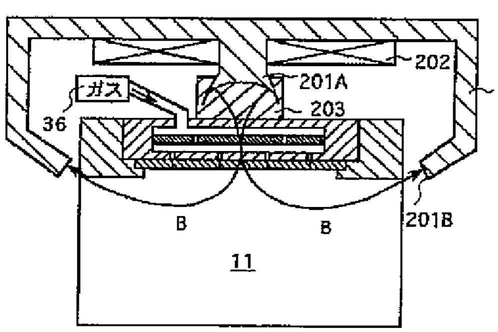
【図２９】

図 29



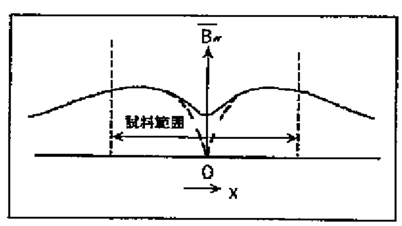
【図１８】

図 18



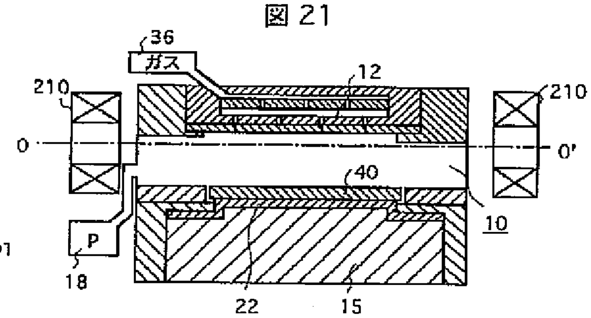
【図１９】

図 19



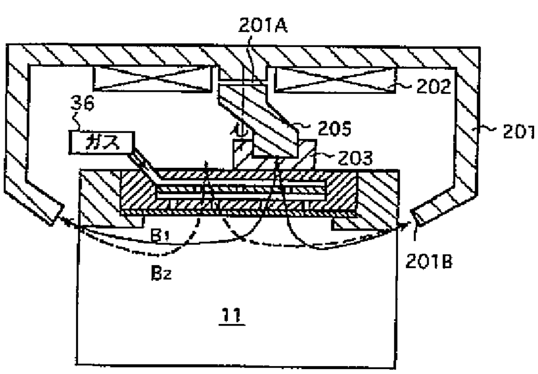
【図２１】

図 21



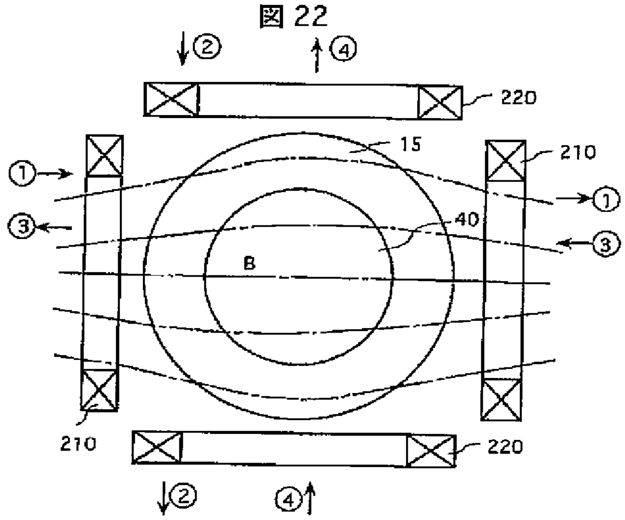
【図２０】

図 20



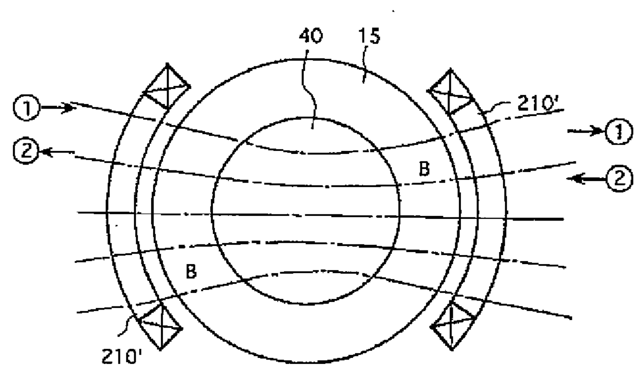
【図２２】

図 22



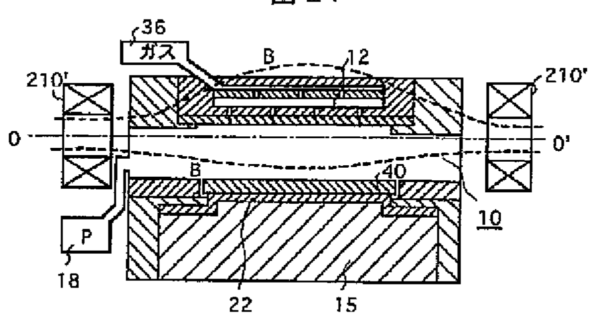
【図２３】

図 23

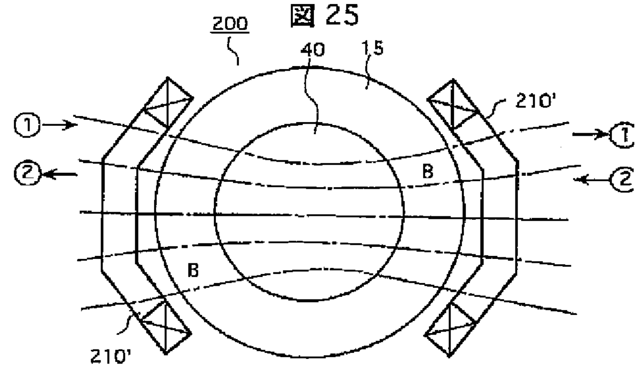


【図２４】

図 24

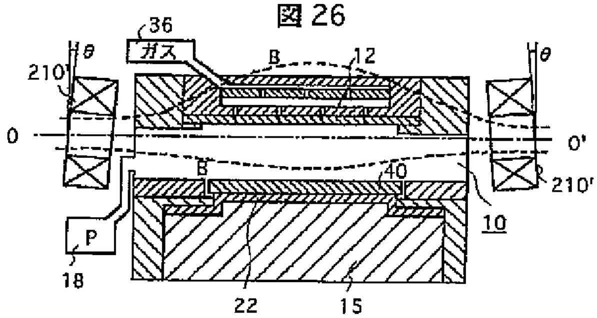


【図２５】



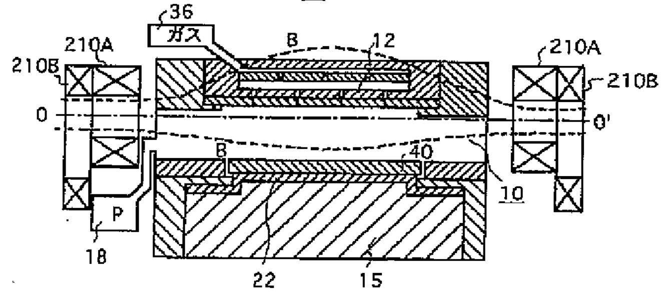
【図２６】

図 26



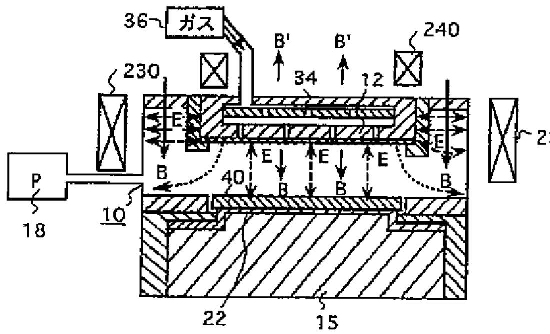
【図２７】

図 27



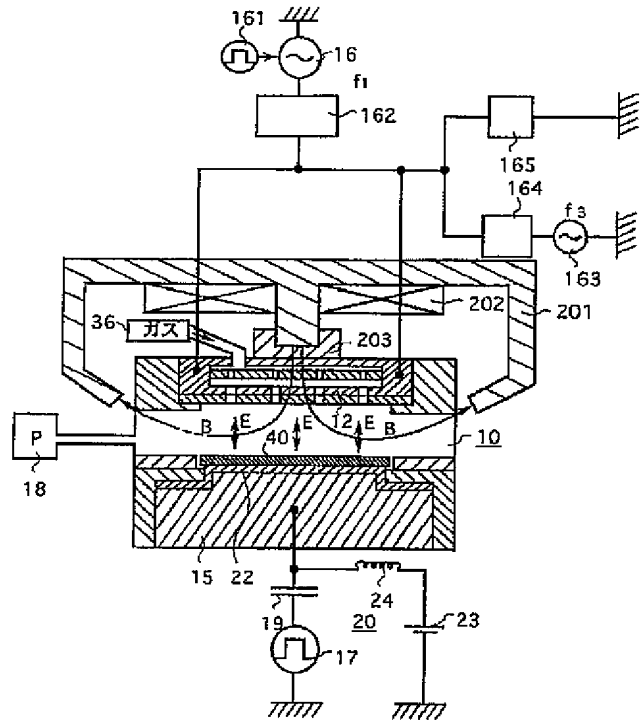
【図２８】

図 28



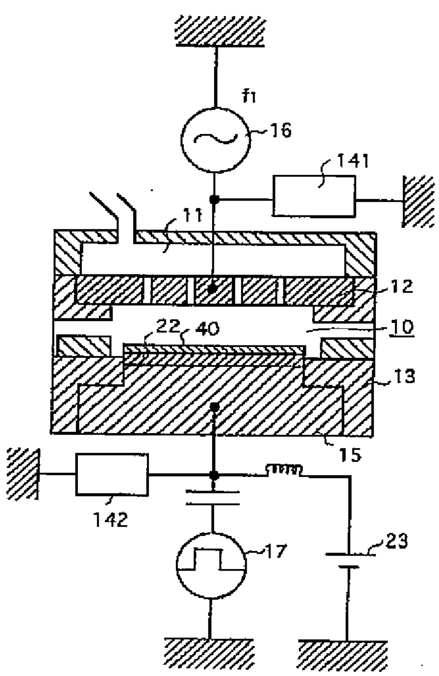
【図３０】

図 30



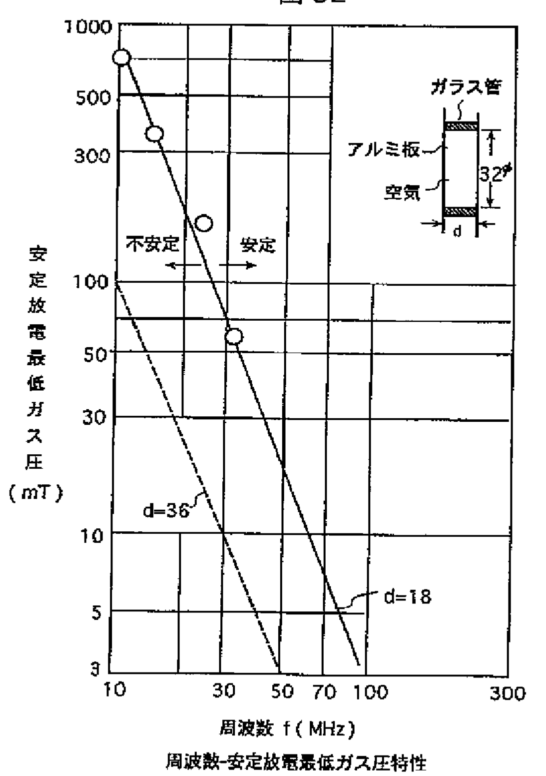
【図３１】

図 31



【図３２】

図 32



周波数-安定放電最低ガス圧特性

【図３３】

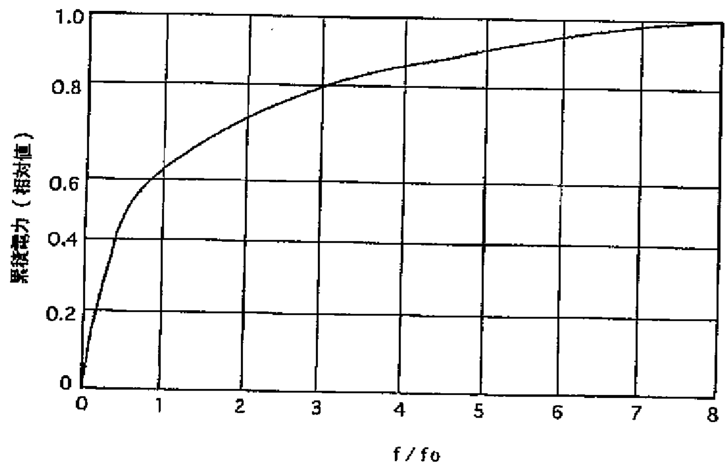
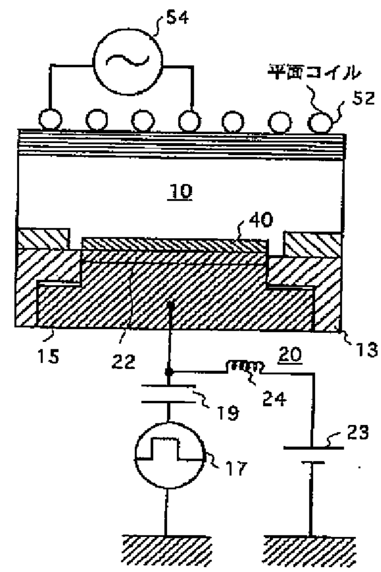


図 33

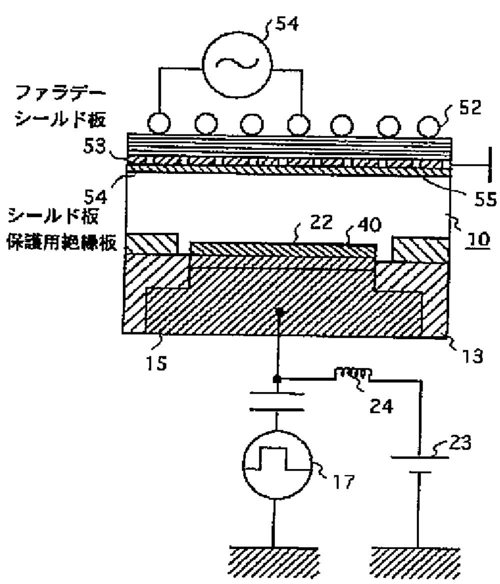
【図３４】

図 34



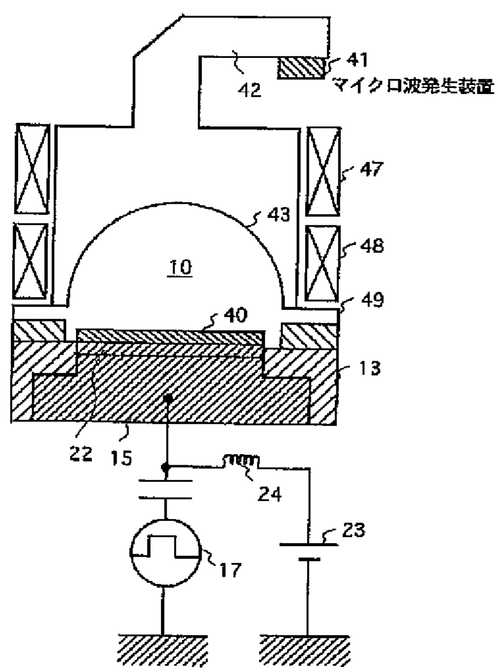
【図３５】

図 35



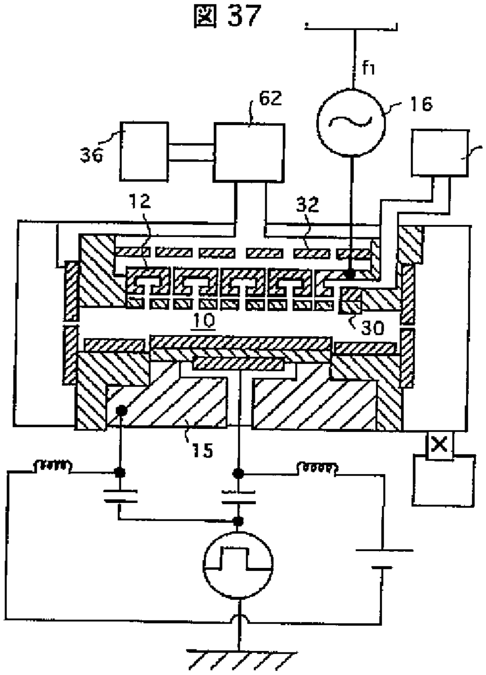
【図３６】

図 36



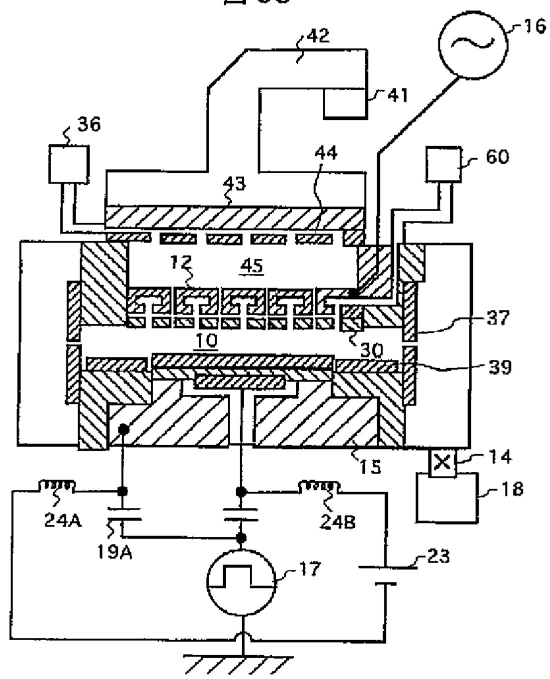
【図３７】

図 37



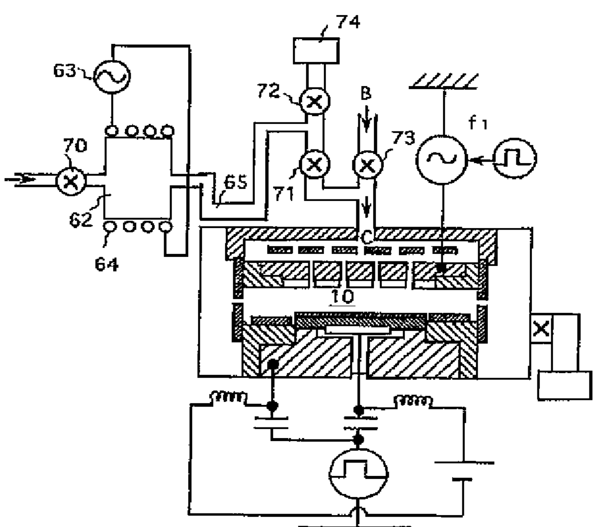
【図３８】

図 38



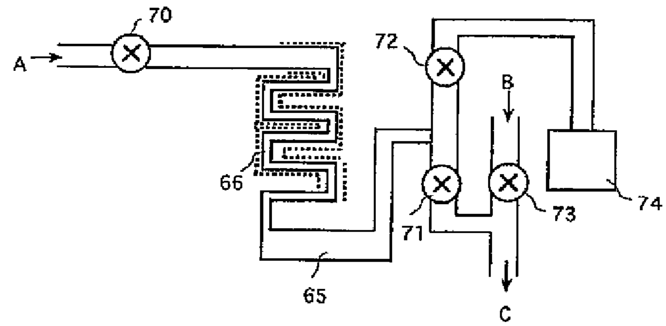
【図３９】

図39



【図４０】

図 40



フロントページの続き

(51) Int. Cl.[6]	識別記号	F I	
Ｃ２３Ｆ　4/00		Ｃ２３Ｆ　4/00	D
Ｈ０１Ｌ　21/205		Ｈ０１Ｌ　21/205	
21/3065		21/68	R

21/68　　　　　　21/302　　　　B

(72)発明者　大坪　徹
茨城県土浦市神立町502番地　株式会社日立製作所機械研究所内

(72)発明者　田地　新一
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

(72)発明者　田中　潤一
茨城県土浦市神立町502番地　株式会社日立製作所機械研究所内